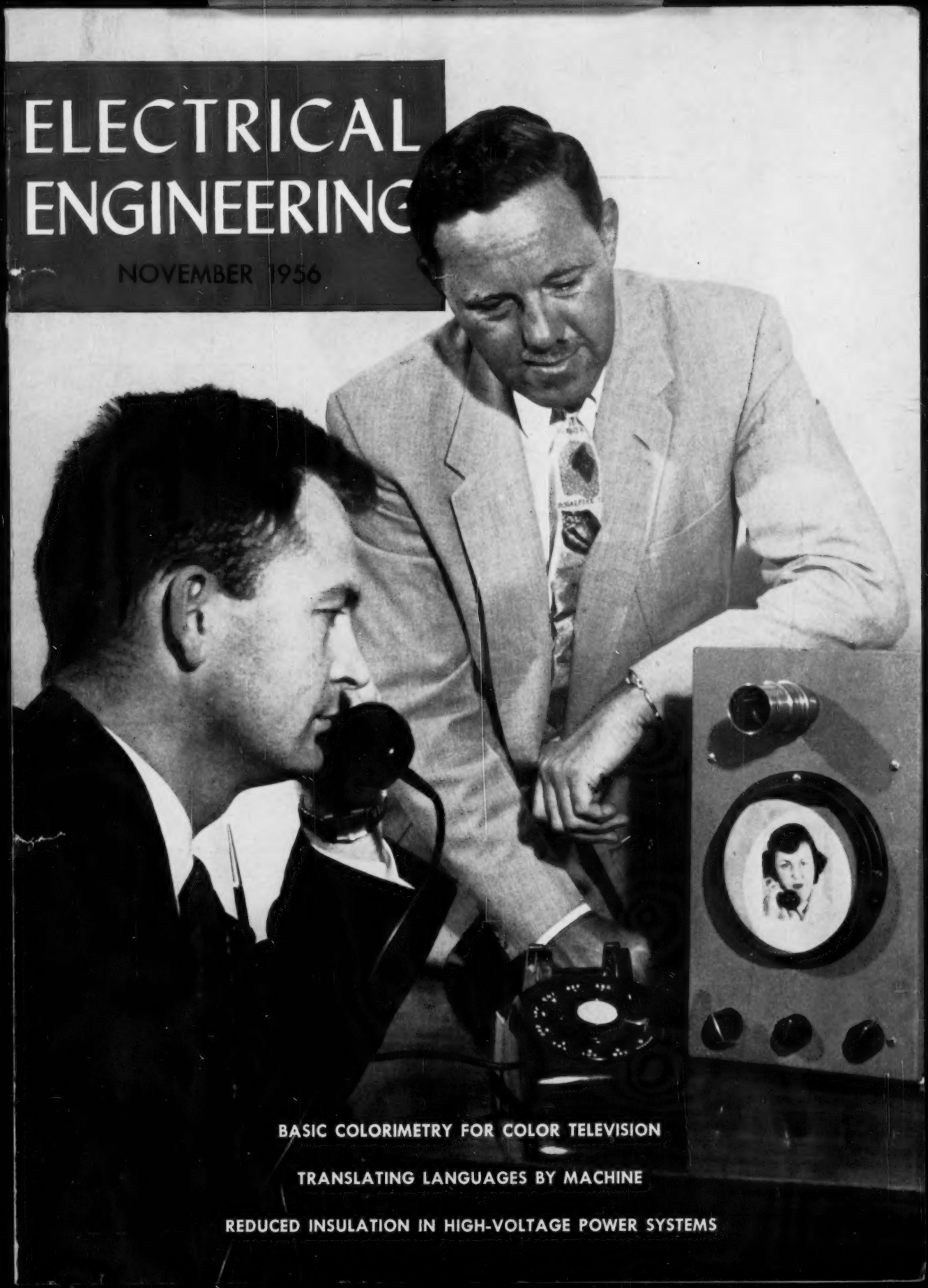
# ELECTRICAL ENGINEERING

NOVEMBER 1956



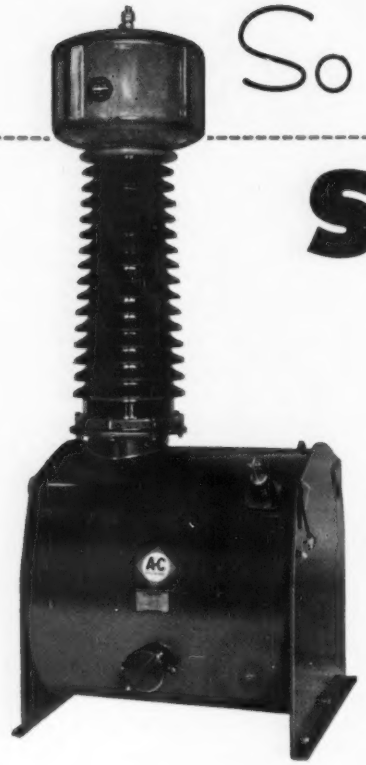
BASIC COLORIMETRY FOR COLOR TELEVISION

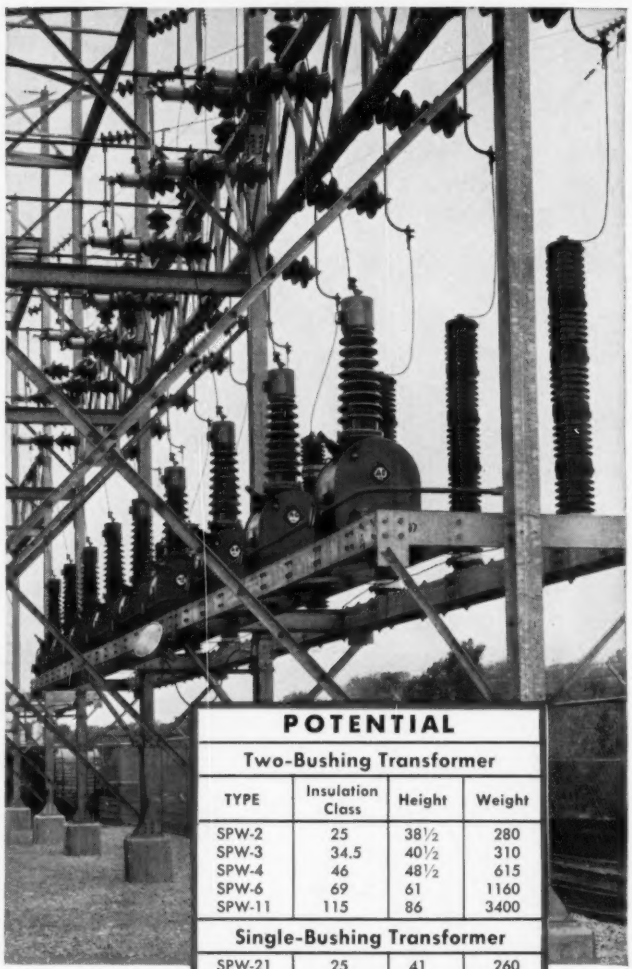
TRANSLATING LANGUAGES BY MACHINE

REDUCED INSULATION IN HIGH-VOLTAGE POWER SYSTEMS

# So Light...SO COMPACT

# So *Easy* to Install





MUCH smaller and lighter than previous designs, new Allis-Chalmers potential transformers cut installation costs and provide maximum handling convenience. Less space and less foundation to mounting structure are required. A fork truck or block and tackle is all that is needed to lift these 69-kv units into position. And, of course, relocating is accomplished just as easily.

*Performance has also been improved* in both ratio and phase angle with the advanced design of Allis-Chalmers potential transformers.

*Many other design features* — features that assure unparalleled dependability and long life — have been incorporated in these modern units. Get the complete story from your local A-C representative or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wis.

| POTENTIAL | | | |
|---|---|---|---|
| **Two-Bushing Transformer** | | | |
| TYPE | Insulation Class | Height | Weight |
| SPW-2 | 25 | 38½ | 280 |
| SPW-3 | 34.5 | 40½ | 310 |
| SPW-4 | 46 | 48½ | 615 |
| SPW-6 | 69 | 61 | 1160 |
| SPW-11 | 115 | 86 | 3400 |
| **Single-Bushing Transformer** | | | |
| SPW-21 | 25 | 41 | 260 |
| SPW-31 | 34.5 | 44¼ | 285 |
| SPW-41 | 46 | 50¾ | 460 |
| SPW-61 | 69 | 63¾ | 950 |
| SPW-111 | 115 | 92 | 2310 |
| SPW-131 | 138 | 112 | 3510 |

**New Ratings** have been added to the Allis-Chalmers line of potential transformers to include higher voltage insulation classes.

A-C ALLIS-CHALMERS

# ALLIS-CHALMERS

A-5164

# ELECTRICAL ENGINEERING

NOVEMBER 1956
Vol. 75, No. 11

*Published monthly by American Institute of Electrical Engineers*

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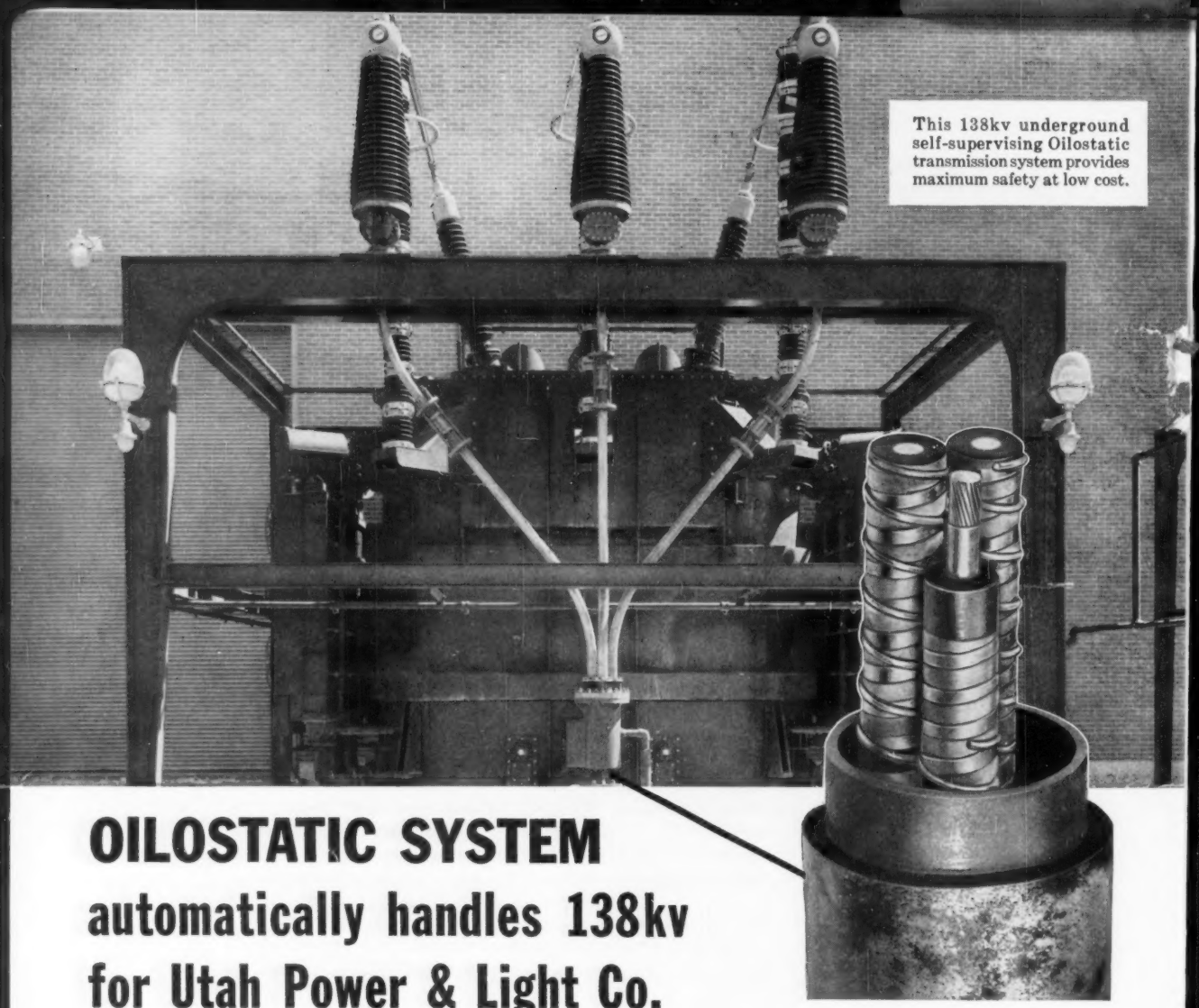

This 138kv underground self-supervising Oilostatic transmission system provides maximum safety at low cost.

# OILOSTATIC SYSTEM automatically handles 138kv for Utah Power & Light Co.

Recently the **Utah Power & Light Co.** started operation of the third section of its new Gadsby steam-electric station to supply the growing power demands of the Intermountain West.

For the all-important high voltage transformer leads, an underground Okonite Oilostatic system was selected and installed by the **Bechtel Corporation.**

This system consists of paper-insulated cables installed in a welded steel pipe filled with oil maintained at 200 psi. The advantages of this type system are:

1. *Proved reliability, ruggedness and stability.*
2. *High normal and overload current carrying capacity.*
3. *Low initial cost compared to duct systems, plus space savings.*
4. *Low maintenance cost through self-supervision.*
5. *Ideal for high voltage transmission in congested areas.*
6. *Provides maximum safety.*

Proof that **Utah Power & Light** can expect to get outstanding performance from this installation is the fact that Okonite Oilostatic systems have been in successful operation since 1932.

For information on Oilostatic which has been installed to handle potentials as high as 230kv, write for Bulletin EG-1044. Address:
**The Okonite Company, Passaic, New Jersey.**

3133

*available with either copper or aluminum conductors*

OKONITE SINCE 1878 *insulated cables*

For more information circle 1 on reader service card.

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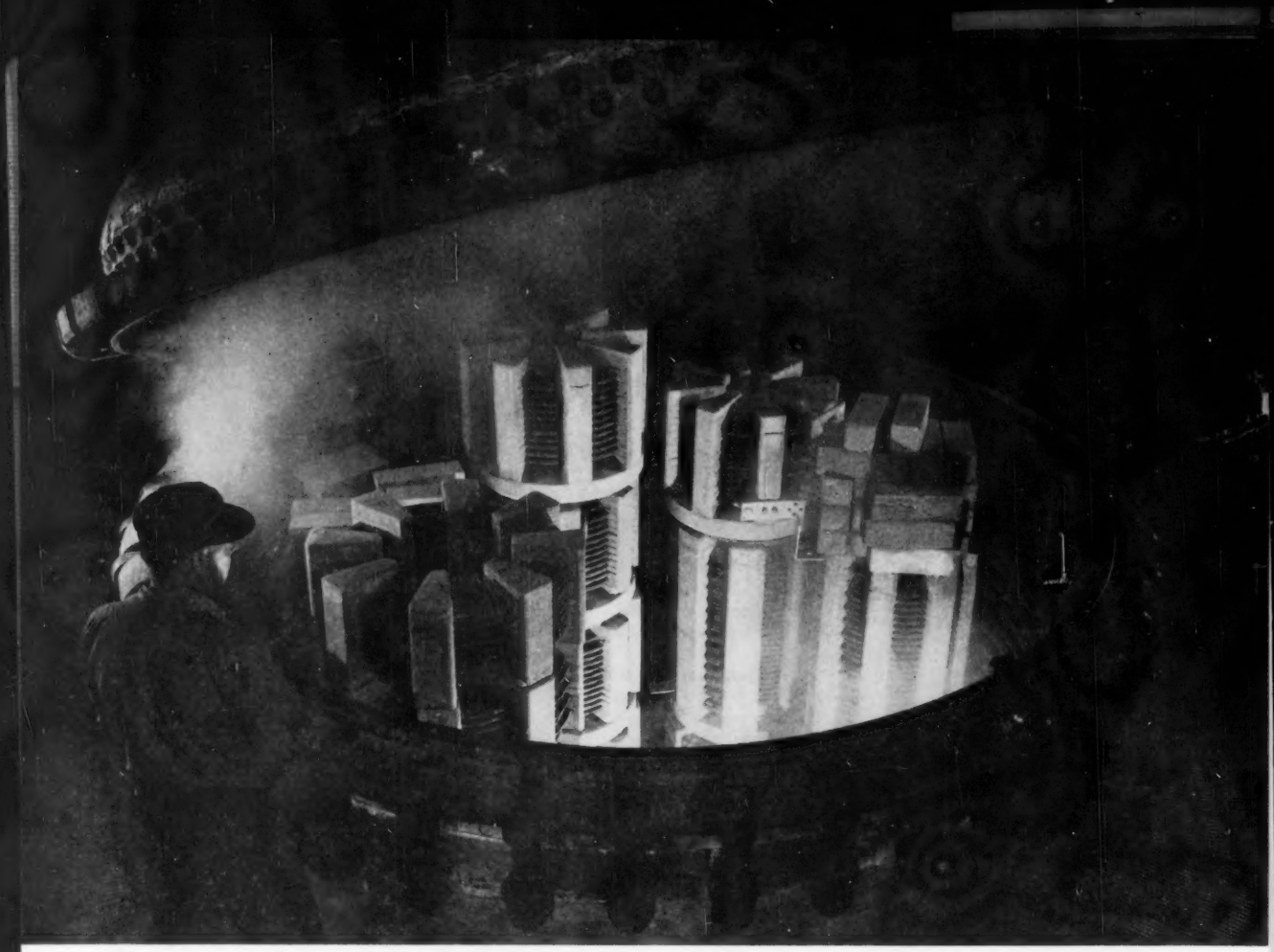
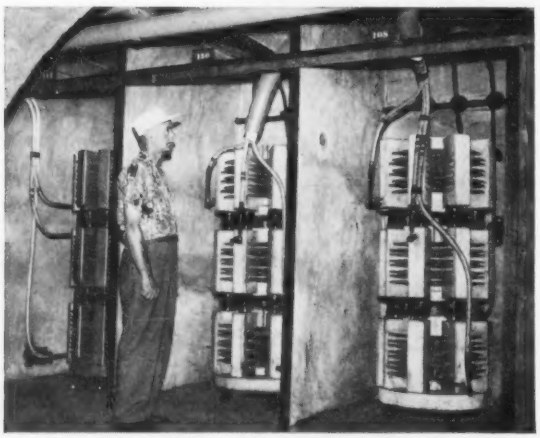


*PROVEN WET-STEAM CURING PROCESS MAKES*

# General Electric cast-in-concrete reactors stronger, more reliable



**37 YEARS OF SERVICE** have been achieved by these G-E cast-in-concrete reactors at Fall River Electric Light Co., Fall River, Mass. Twelve reactors, installed in 1919, are as strong as ever and have required practically no maintenance.

**RELIABILITY** that begins at the moment of installation and lasts through a longer life is assured to you by General Electric's time-proven methods of manufacturing cast-in-concrete reactors. Using its exclusive wet-steam curing process, G.E. achieves in two days a degree of concrete curing which would be obtained only after several weeks of normal, in-service curing. This unique 180° C steam bath gives you stronger, more reliable reactors than any other curing method in use today.

**PROOF OF THE STRENGTH** of properly cured concrete reactors is demonstrated daily by thousands of G-E reactors in service across the country (see photo left). For other benefits of G-E reactors, contact your local G-E Apparatus Sales Office or write General Electric Company, Schenectady 5, New York. 422-32

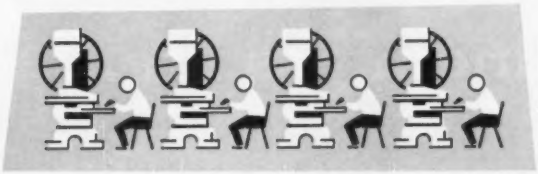
*Progress Is Our Most Important Product*

GENERAL ELECTRIC

For more information circle 2 on reader service card.

# ALSIMAG® PRESSED CERAMICS for variety!

**More Materials.** Alumina, Cordierite, Forsterite, Magnesium Silicate, Steatite, Titanium Dioxide, Zircon, Zirconium Oxide... to name a few! Custom formulations of special-characteristic materials to meet special needs.



**More Production Facilities.** The right combination of equipment for efficient and economical production in any quantity, large or small! **FAST DELIVERIES!** Greatest lineup of high-speed automatic presses in the industry: Small tablet varieties, multi-impression rotaries, huge hydraulics. Tooling from our own die shops. Vast kiln space — including controlled atmosphere, continuous firing.

**More Latitude in Design.** Simplest to most complex. Broad tolerance shapes supplied at prices below those of almost any other material. Precision tolerances on intricate shapes. Over half a century of specialized experience in producing "impossibles." Free redesign service for lower production costs, easier assembly, improved performance. AlSiMag Extras: High temperature metalizing, metal-ceramic combinations.

**Why not see what AlSiMag can do in your application? Blueprint or sketch plus outline of operating procedure will bring you complete details.**

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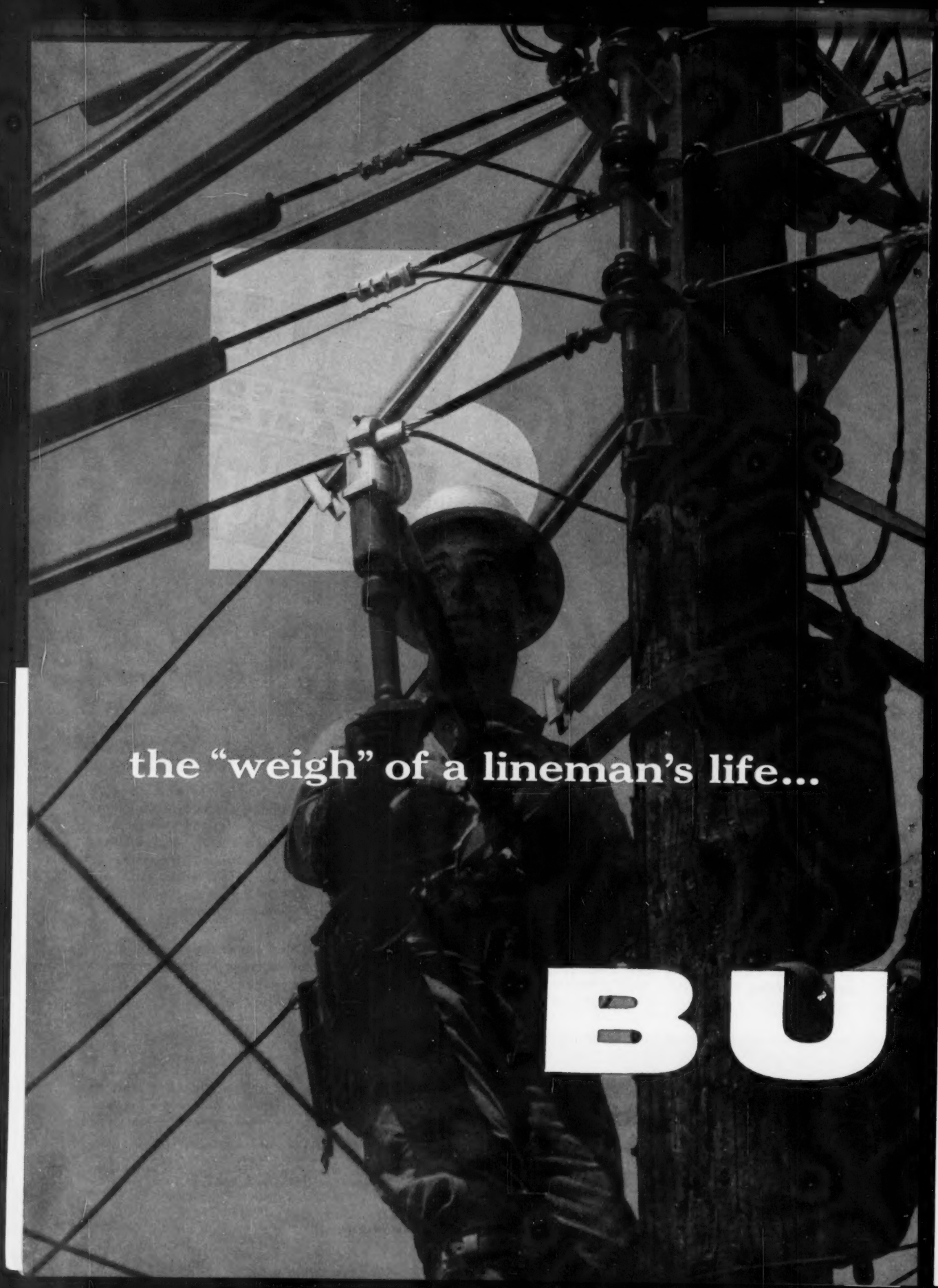
**For more information circle 3 on reader service card.**

**Circle 4 ▶**


the "weigh" of a lineman's life...
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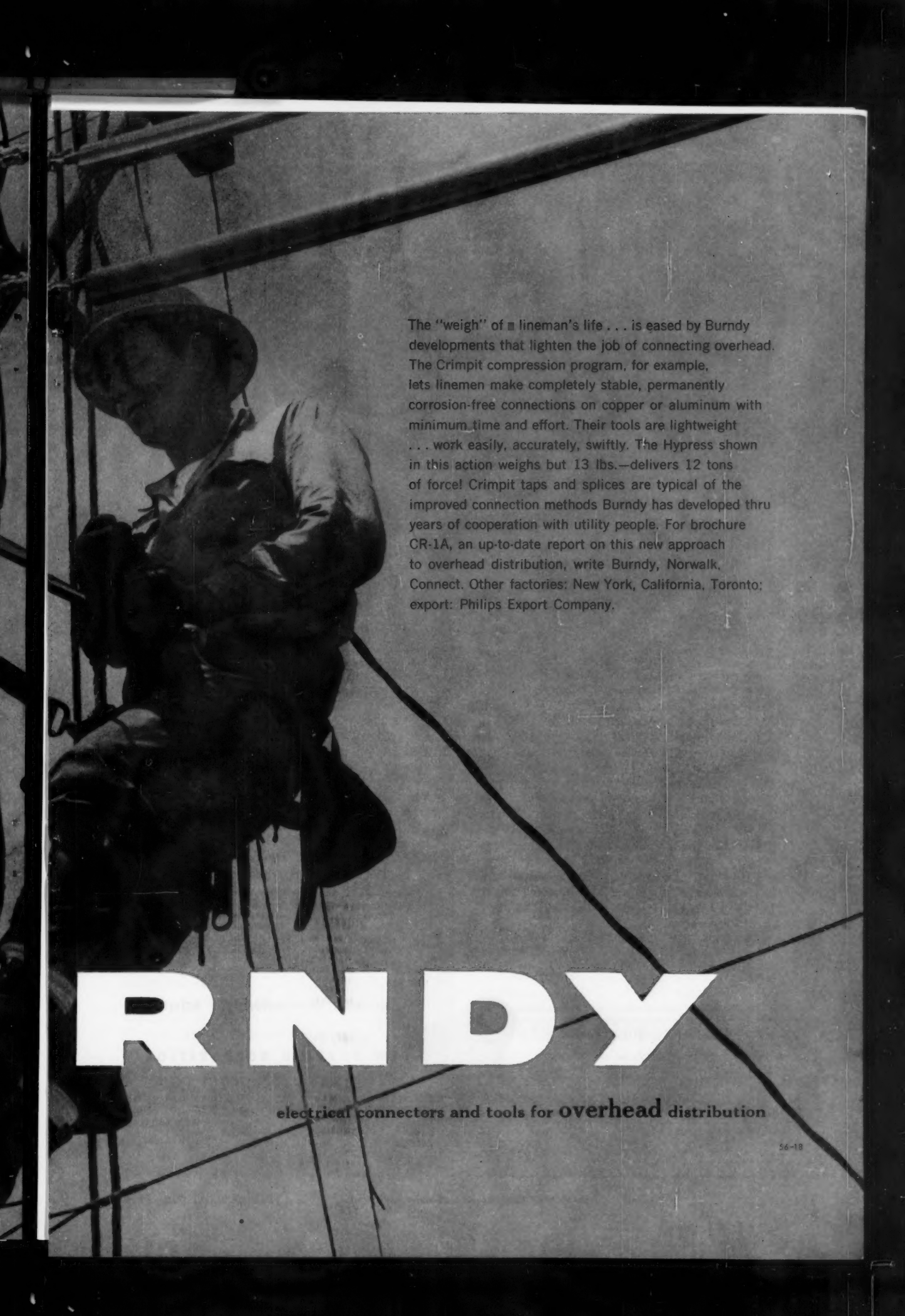

The "weigh" of a lineman's life . . . is eased by Burndy developments that lighten the job of connecting overhead. The Crimpit compression program, for example, lets linemen make completely stable, permanently corrosion-free connections on copper or aluminum with minimum time and effort. Their tools are lightweight . . . work easily, accurately, swiftly. The Hypress shown in this action weighs but 13 lbs.—delivers 12 tons of force! Crimpit taps and splices are typical of the improved connection methods Burndy has developed thru years of cooperation with utility people. For brochure CR-1A, an up-to-date report on this new approach to overhead distribution, write Burndy, Norwalk, Connect. Other factories: New York, California, Toronto; export: Philips Export Company.

# BURNDY

electrical connectors and tools for **overhead** distribution

56-18

# The Case of WASTED HORSEPOWER

**or**

***"Over-motoring" is outmoded by Dow Corning Silicones***

SCENE: Pump room, Anyplant, U. S. A.

CHARACTERS: TINY H.—a 5 hp Class H motor insulated with Dow Corning Silicones. BLUSTER A. — a 7½ hp Class A motor.

TINY H: You're goofing-off again! Why don't you try moving a bigger load now and then?

BLUSTER A: Nuts to you, Tiny. I'm working hard enough keeping this little pump going.

TINY H: But you're strong enough to drive a bigger pump . . . or are you?

BLUSTER A: That's enough. I should worry—the engineers who put me here figured I might have to carry a 6 hp load—er—once in a while, at least.

TINY H: Sooo what! I'm rated to match our average load. My silicone insulated innards give me extra muscles to carry any overloads. Why—I could pump a 7 hp load and still be here when you're dead and gone.

BLUSTER A: Shut up, Tiny! Somebody might hear you.

TINY H: Okay, fat stuff, but you can't hide the facts forever. Mark my nameplate—one of these days the boss will figure out how much money you're wasting and you'll have had it.

**You can match the load . . .**
**let Silicones carry the overload**

Lazy motors cost money! Why continue to pay a fat premium for motors that make kid's play of their average work load? Today, you can save money by using silicone insulated motors rated to match your average load. Their built-in service factor of 25 to 50% will handle most intermittent overloads or loads that can't be matched in standard frame sizes.

***Remember, over-motoring is outmoded***

*Get sources for silicone insulated equipment—mail coupon today*

Dow Corning Corporation, Dept. 4111, Midland, Mich.

*Please send me sources of supply for new Silicone (Class H)* ☐ Motors ☐ Transformers

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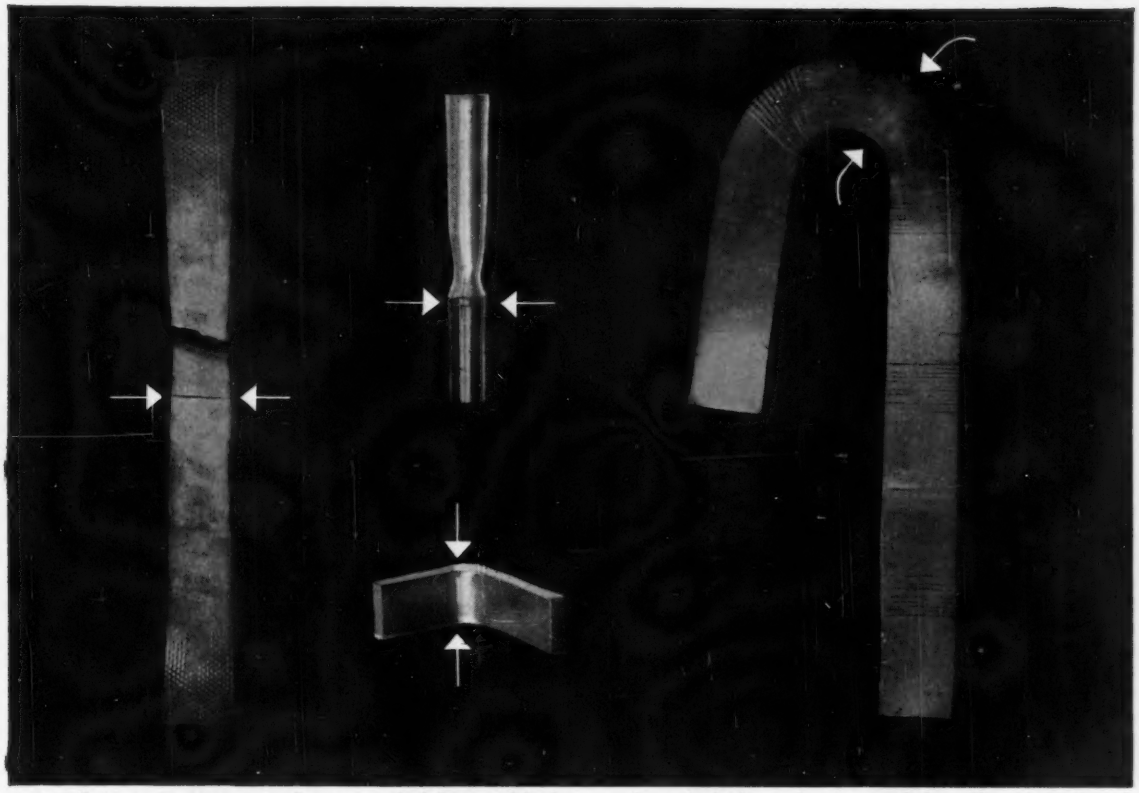

**LEFT:** Full-size tension test piece of copper necked down and broke away from the high-speed resistance flash welds. **CENTER:** Round (1.25" diam.) and rectangular (0.50" x 1.50") aluminum conductors resistance–flash-welded to copper. In the 90-degree bend test, fracture did not occur at the weld. In tension test, aluminum necked down, but the weld was unaffected. **RIGHT:** Test samples of copper (.344" x 2.25") bent edgewise at the welded joint, without fracture.

# High-speed resistance Flash Welds offer New Freedom in design of Continuous Conductor Assemblies

After considerable experimentation and testing, Anaconda American Brass Ltd. in Canada is now joining conductors to form continuous assemblies for generator coils with high-speed resistance flash welds. A 400-KVA Thomson Synchromatic Flash Welder is used.

Proof of the strength of the welds is indicated by photos of the test pieces above.

The tension test piece, shown at the left, necked down and broke in the copper, away from the weld.

*Size tested.....0.329" x 2.251", round corners*
*Maximum load.....22,900 lbs.*
*Ultimate tensile strength...31,200 lbs. per square inch*
*Elongation in 2 inches at fracture.....70 per cent*
*Elongation in 2 inches across the joint.....35 per cent*

These high-speed resistance flash welds offer new freedom in the design of continuous conductor assemblies. Other methods of strong, ductile welding, braze-welding, and silver-alloy brazing may also be used to join Anaconda High Conductivity Copper Conductors in the shop or in field erection. Write for the new edition of Publication C-25, "Anaconda Copper for Electrical Conductors," and Publication B-13, "Anaconda Welding Rods." Write: Technical Department, The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario, Canada.

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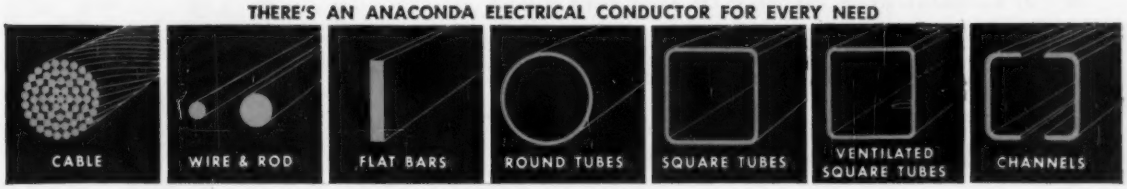
**ANACONDA®** COPPER CONDUCTORS

**THERE'S AN ANACONDA ELECTRICAL CONDUCTOR FOR EVERY NEED**






For more information circle 6 on reader service card.



Circle 7 ▶

# NOW... LOADBUSTER

## Breaks Loads with Open Cutouts

LOADBUSTER is ruggedly built for repetitive service with S&C open cutouts wherever they are applied. There is no broken link to replace after switching. Both the cutout and LOADBUSTER are ready immediately for repeat service. Moreover, the high interrupting capability of LOADBUSTER permits load breaking even when the cutout carries the 200 ampere disconnect blade. Also, it can interrupt any steady overload the cutout may be carrying (as much as 200 amperes with a 100 ampere link).

- **Put LOADBUSTER on each of your line trucks**
- **With it your lineman is ready to break the circuit instantly up and down your distribution system**
- **It just hooks across an S&C disconnect or S&C open-type cutout to provide safe, arc-free interruption**

# ...A *Portable* LOADBREAK TOOL

With the advent of the revolutionary LOADBUSTER, an entirely new concept in circuit switching is born, one that brings complete, positive, safe switching for distribution systems within the reach of any utility's pocketbook. For LOADBUSTER is a circuit interrupting device which is portable, is repetitive, and is universal.

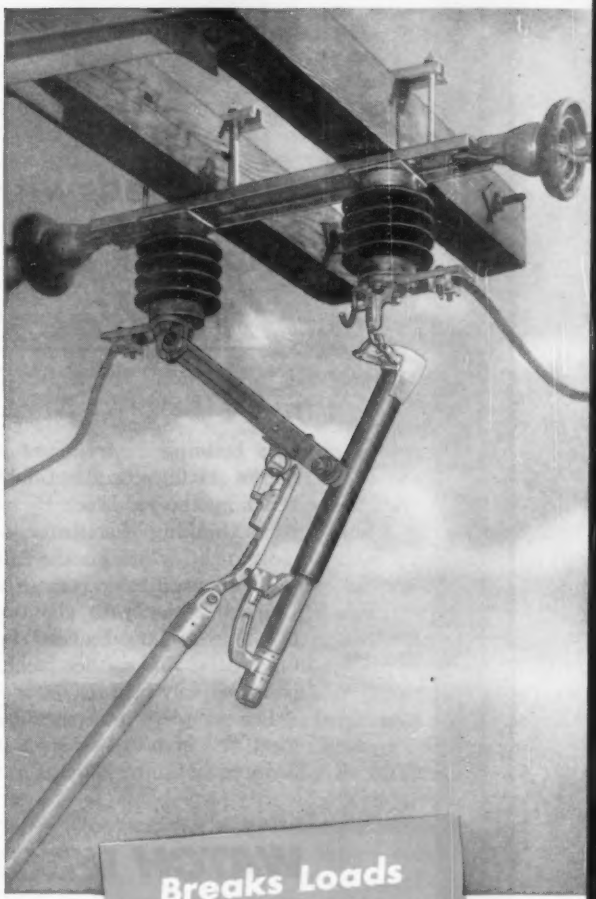
Disconnects and cutouts inherently have no positive switching capability. To get it, some interrupting means must be built into them. For example, a link breaking device must be built into an open cutout; an interrupting unit into a disconnect which then makes it a load interrupter switch. This costs money !!! BUT, bringing the interrupting device to the disconnect or cutout only when needed eliminates this cost . . . that's what LOADBUSTER does . . . it's a loadbreak tool.

With LOADBUSTER you can drop all tedious, uneconomical, and unsafe switching practices. Attached readily to a universal pole, LOADBUSTER is simply hooked across the upper contact of a disconnect or cutout which is then opened in the normal way. It's just that easy! There's no arc, no link breakage, no fuss, no worry, no contact burning, and no danger to the operator. After use, LOADBUSTER is returned to the truck ready for instant use again anywhere.

LOADBUSTER can be used over and over again. It will withstand daily field usage over a long period of time without requiring maintenance. On the other hand, because it's portable, it's available for easy inspection. It's a circuit interrupting device that can always be kept in top-notch condition.

LOADBUSTER is operable at any distribution system voltage through 14,400 volts, and is able to break all load currents through 400 amperes, as well as associated magnetizing and charging currents. It can also switch all pole-top capacitor banks.

Ask for Descriptive Bulletin No. 730.




LOADBUSTER provides arc-free circuit interruption with S&C disconnects rated 400 amperes and 14.4 kv. It also will be usable with an S&C pole-top regulator switch.

S&C

*Specialists in High-Voltage Circuit Interruption since 1910*

**S&C ELECTRIC COMPANY**

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POWER FUSES • CUTOUTS AND FUSE LINKS • LOAD INTERRUPTERS • METALCLAD SWITCHGEAR

# Designed with the architect and engineer in mind . . . Westinghouse *Life-Linestarters**

Any building deserving of an architect and an electrical engineer also merits the finest in functional equipment. For, this is the very life of any building; the yardstick by which its efficiency is measured. That's why, when thinking of controls—and, when looking for a starter—you should look to the Westinghouse Life-Linestarter.

There are 5 basic reasons why you should select a Westinghouse Life-Linestarter for your clients: (1) There's a complete and uniform line; (2) They're far-advanced in design; (3) Westinghouse offers complete application and service facilities; (4) Delivery is immediate; (5) They are competitively priced.

For complete information on Westinghouse Life-Linestarters, call your local Westinghouse sales engineer—or, write Westinghouse Electric Corp., 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-21975-X

*Trade-Mark

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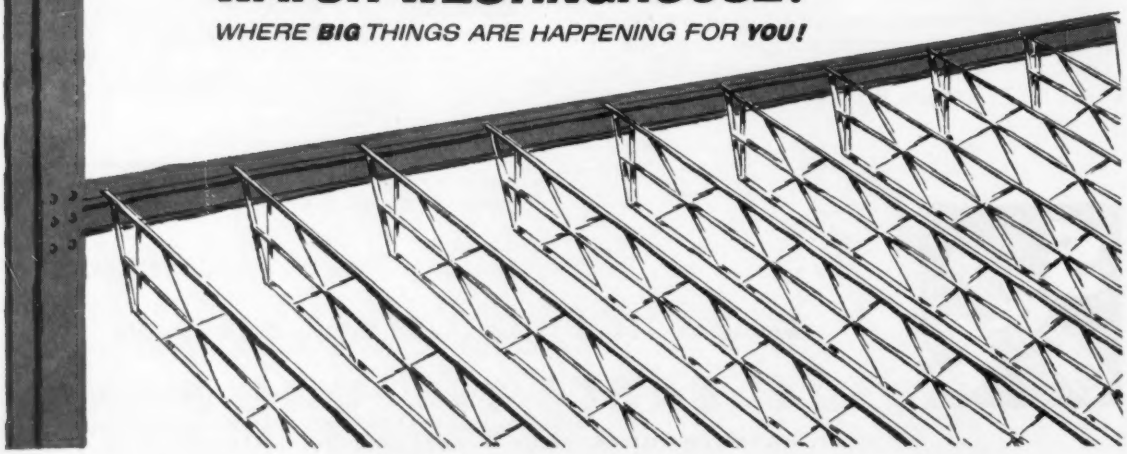



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# A Versatile Remote Control System Using a Switching Matrix Decoder

C. E. CHAMPION H. B. SCHULTHEIS, JR.

**The features and operation of a new frequency code remote control system are described. Among its advantages are relative simplicity and high information capacity, with no need for synchronization between transmitting and receiving stations.**

ONE OF THE OLDEST and most widely used techniques in the communications art is the electrical transmission of audio-frequency tone signals for remote selection and control of various types of machines and apparatus. These techniques have probably attained their highest state of development and utility in such applications as remote supervisory control of electric power stations, radio stations, pumping stations, and for selective calling in vehicular communication systems.

Although present-day tone signaling systems differ markedly in physical construction and circuit details, all have one basic principle in common: the transmission over a single communication channel of a discrete combination of audio-frequency tones to effect one of several predetermined remote control functions. Each combination of tones is a distinct code which is accepted by one, and only one, of the several remotely controlled devices, and rejected by all the others. The individual tones comprising a coded signal may be time spaced, as in pulse code systems, or frequency spaced, as in frequency code systems. Certain remote control systems use a combination of these two basic methods. For a given remote control application, the choice of the optimum methods of coding and transmission involves compromise between equipment complexity, bandwidth, rates of transmission, the number of control functions to be accommodated, environmental conditions, and the degree of reliability required.

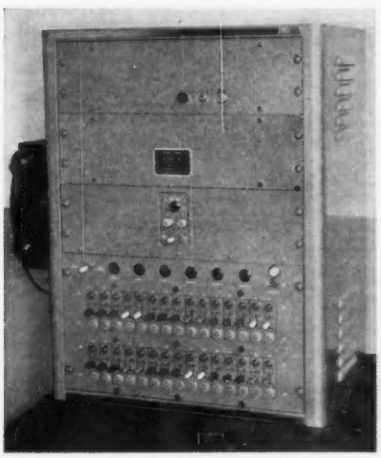

Fig. 1. Control station equipment used in frequency code supervisory control systems.

Conventional telephone lines, power line carrier-current channels, vhf, and microwave radio links are communication media which are widely used in tone signal remote control systems.

## FREQUENCY CODE REMOTE CONTROL SYSTEM

A PURE FREQUENCY CODE data transmission system has been used successfully in high-accuracy telemetering applications.[1] This system is relatively simple, possesses a high information capacity, and has the unique advantage of requiring no synchronization between transmitting and receiving stations. Recently, the frequency code system has been adapted for use as a supervisory control system (Electro-Span) designed for ON-OFF remote control of such equipment as motors, pumps, actuators, valves and switchgear over voice-bandwidth telephone lines or radio channels. Typical control station equipment and remote station equipment are illustrated in Figs. 1 and 2.

A simplified block diagram of the frequency code remote control system is shown in Fig. 3. In this elementary system, the control station consists of a group of tone oscillators of different frequencies, a coding switch for each remote control function, an output amplifier, and a power supply. The remote station includes an input amplifier, a group of tone detectors tuned to the frequencies of the tone oscillators, and a novel decoding circuit which converts each incoming frequency code into a signal actuating one of the several load-control relays. The individual tones comprising each coded control signal are transmitted and received simultaneously. Separate control codes may be transmitted in any desired order, the rate being limited only by the speed and skill of the operator.

Each control code consists of a discrete combination of presences and absences of the available tones which, taken together, may be regarded as a binary number with each tone representing one digit. When a control switch is operated, certain tones are connected through the switch to the output amplifier, and all other tones are blocked. This composite tone signal (tone chord) is amplified and transmitted over the communication link to the remote station where it is again amplified and fed to the common input circuits of the group of tone detectors. Bandpass filters at the input of the tone detectors separate the com-

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posite signal into its individual tone components, each of which is amplified within its respective tone detector. A multicontact relay connected to the output of each tone detector is energized when the proper tone is present in the received code and remains de-energized if that tone is absent. Thus, the group of tone detector output relays reproduces momentarily the binary number applied to the input of the system through closure of the control switch.

## TONE CHANNEL EQUIPMENT

THE TONE FREQUENCIES normally used in the frequency code remote control system range from 500 to 3,500 cps (cycles per second), with 200-cps separation between adjacent tone channels. Ten tones can be accommodated within the spectrum 500 to 2,300 cps provided by an ordinary voice-quality telephone line or radio channel. The input and output amplifiers have sufficient gain to permit a signal-path attenuation of as much as 30 db.

A single tone oscillator and a tone detector are illustrated in Fig. 4. Both units are of plug-in construction, using printed circuit wiring. Both are designed for continuous unattended operation. The tone oscillator uses a *6SN7GT* twin triode connected in a stabilized Wien bridge circuit. The maximum frequency shift is $\pm 1/2$ per cent within the ambient temperature range $-20$ C to $+80$ C, and when subjected to supply voltage variations up to $\pm 20$ per cent.

The tone detector consists of a simple bandpass filter, a *6SJ7* voltage amplifier, and a *6AG7* power amplifier-rectifier. An input tone of 0.75 volt rms of the proper frequency produces a d-c output of 0.8 watt, which is sufficient to actuate a multicontact telephone-type relay. The bandpass filter has a 3-db bandwidth of 60 cps, and provides an adjacent channel attenuation of approximately 28 db.

## NUMBER OF TONE CHANNELS AND CODE SELECTION

THE NUMBER OF TONE CHANNELS required in a particular application depends upon the number of remote control functions to be performed. An 8-tone system provides sufficient capacity for 32 ON-OFF control functions, and a typical 9-tone system can accommodate 46 ON-OFF functions. In these systems, one of the tones, called a "guard tone," conveys no control code information. The guard tone accompanies each transmitted control code, providing a frequency redundancy which reduces the possibility of inadvertent response of the receiving equipment to noise or interfering signals.

In a frequency code signaling system, the maximum number of individual codes which can be generated is $2^n$, where $n$ is the number of tones available. Using one tone as a guard tone, the number of codes is reduced to $2^{n-1}$. An 8-tone system, therefore, has a capacity of $2^7$, or 128, separate codes, providing theoretically 64 ON-OFF functions.

However, there are practical reasons why all of the codes cannot or should not be used. For example, the single code with all tones absent is unusable because it cannot be distinguished from the normal stand-by condition when no control signals are being transmitted.

Fig. 2. Remote station equipment used in frequency code supervisory control systems. ▶

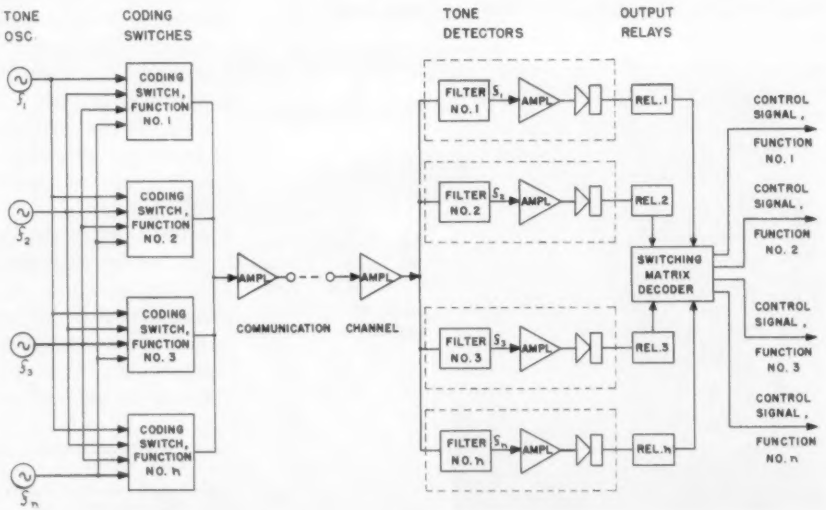



Fig. 3. Simplified block diagram of frequency code remote control system. ▼

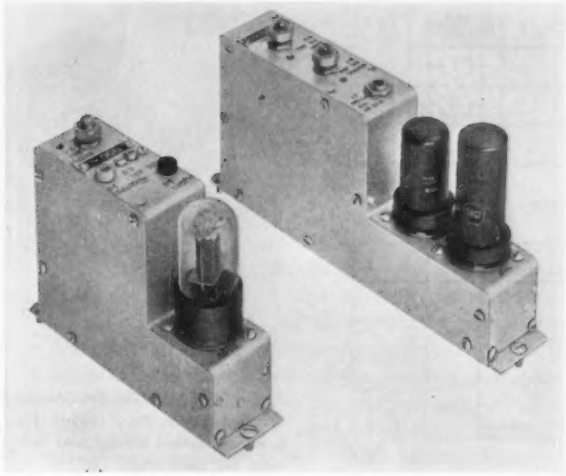


Fig. 4. Tone oscillator and tone detector.

System reliability can be somewhat improved by deleting those codes which are comprised of a large number of ON tones. This reduces the degree of voltage regulation required of the tone detector high-voltage power supply, and also reduces the maximum system noise level due to intermodulation and crosstalk. The limit placed on the maximum number of tones present in a transmitted code is somewhat arbitrary, but use of codes of up to four ON tones (plus guard tone) has proved to be a satisfactory compromise in the Electro-Span frequency code system.

Deletion of certain codes can also simplify the decoder circuitry through reduction in the number of contacts required in the tone detector relays. With the type of decoding circuit used in the frequency code system, only those codes which require no more than four Form C contacts (4-pole double-throw) on the tone detector output relays are used.

## THE SWITCHING MATRIX DECODER

THE PRINCIPLES OF OPERATION of the Electro-Span frequency code remote control system have been described up to the point where the binary control signal has been received, detected, and held momentarily in the tone detector output relays. At this point in the system, the coded signal must be converted into a single signal which actuates the proper ON-OFF load control relay.

The common method of connecting relay contacts to select one of a number of load elements is in a "tree circuit."[2] This method is satisfactory where the number of controlled devices is few (not more than eight or so), but becomes cumbersome and somewhat costly if a larger number of load elements must be controlled. Some saving in the required number of relay contacts may be effected by "folding" parts of the tree circuit, but this is still unsatisfactory where many load devices must be controlled.

In the frequency code remote control system, this problem has been largely solved through the use of a switching matrix circuit adapted from the previously described frequency code telemetering system.[1] The reduction in the required number of relay contacts offered through use of this circuit is illustrated in the 4-digit matrix of Fig. 5.

The circuit of a 7-digit switching matrix is shown in Fig. 6. The 7-tone detector output relays are divided into two groups, each of which is arranged in a "transfer tree" circuit.[2] The contacts of one group of relays are connected to the horizontal conductors of the matrix, and the contacts of the second relay group are connected to the vertical conductors. In the illustrated matrix circuit, there are 8 horizontal conductors and 16 vertical conductors, making 128 crossovers. This corresponds to the 128 binary numbers of a 7-digit code. However, because of code pairing only 64 of the available codes, and therefore only 64 crossovers in the switching matrix, are used in this example. At each of these 64 intersections a load control relay coil, in series with a neon lamp, is connected between a horizontal conductor and a vertical conductor.

When a binary control signal is received and held in the tone detector output relays, the relay contacts apply full matrix voltage to only one of the intersections, causing the load control relay bridged across that intersection to operate. The neon lamp connected in series with each load control relay coil serves to isolate the selected coil from all other coils in the matrix, thus preventing inadvertent operation of one or more unselected relays through "sneak circuits" which would exist if no isolation were provided.

In the system illustrated in Figs. 1 and 2 the load control relays are of the opposed-coil, mechanical-latch type. One

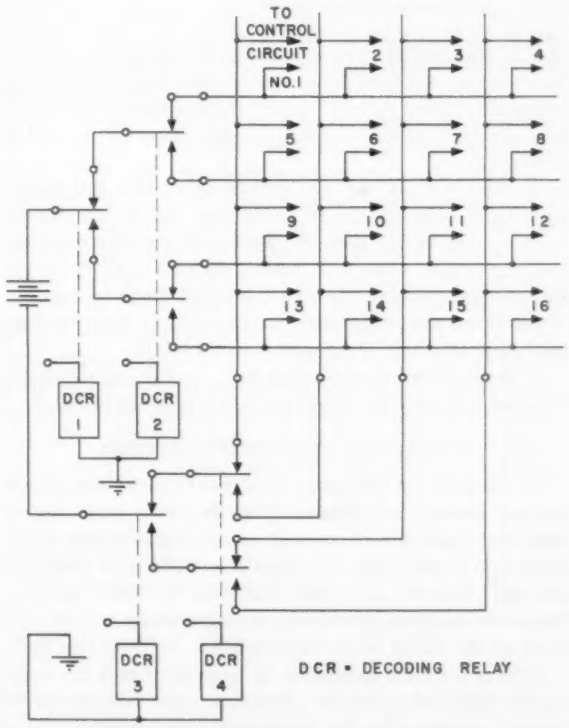
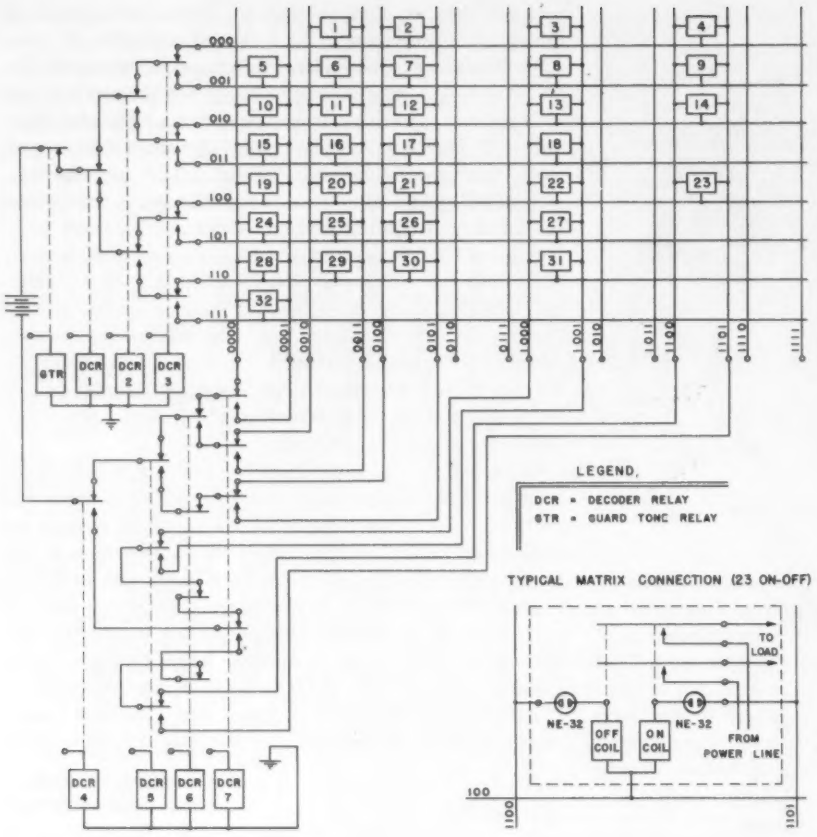



Fig. 5. Four-digit matrix decoding circuit for 16 control functions (maximum two contacts on second and fourth relays).



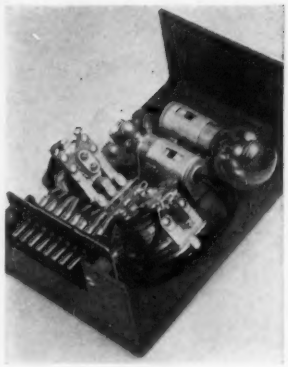



Fig. 6 (*left*). Seven-digit switching matrix decoder. Fig. 7 (*above*). Plug-in matrix element, showing load control relay and neon lamps.

coil of the latching relay is bridged across an ON-code intersection, and the other across an OFF-code intersection, permitting direct control of motors, actuators, switchgear, and similar apparatus having power demands of up to 500 watts.

In the circuit of Fig. 6 it will be noted that the guard-tone relay contacts are in series with the matrix supply voltage. By using a slow-operate coil on the guard-tone relay, the matrix voltage is applied only after all the other tone-detector output relays have selected the proper matrix intersection, thus preventing errors resulting from random operating sequence of the tone detector relays.

A plug-in load control relay unit, containing the 2-coil latching relay and the two neon lamps, is shown in Fig. 7.

## AUXILIARY EQUIPMENT FEATURES

IN ADDITION TO THE BASIC FUNCTION of providing remote ON-OFF control, the Electro-Span frequency code system includes a number of technical operating features which enhance its usefulness and reliability. Many of these additional features have been included to meet the performance objective prescribed for supervisory control systems by the AIEE Joint Subcommittee on Telemetering.[3]

One of the most important of these features is the automatic verification of the reception and completion of control signals. In the frequency code system, this is accomplished through transmission of a confirming tone code from the remotely controlled equipment back to the control point via the same communication channel. After reception and execution of a control signal, tone oscillators located in the remote station generate a confirming code which is transmitted to a set of tone detectors in the control station. Reception of the confirming code causes an ON lamp or OFF lamp to light near the control switch, thus indicating that the control order was received and acted upon at the remote station. The equipment and circuitry used in the transmission and reception of confirmation codes are duplicates of those previously described for transmission and reception of control codes. The entire process of control, actuation, and confirmation is accomplished in less than 1/2 second.

Another auxiliary feature in the 8-tone system is automatic transmission from the remote station of up to six warning codes. These codes are transmitted whenever a predetermined fault occurs, such as overtemperature in a generator bearing, stoppage of a pump, or unintended tripping of a circuit breaker. The warning code, when received at the control station, causes a red lamp to light and sounds a buzzer. The six warning circuits may be tested manually by transmitting a test code from the control station to the remote station, whereupon the warning codes are automatically synthesized and transmitted sequentially to the control station, lighting the warning lamps.

In over eight months of test and operation, the Electro-Span frequency code remote control system described herein has proved to be accurate and dependable.

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# Analytical Design and Evaluation of Electromagnets

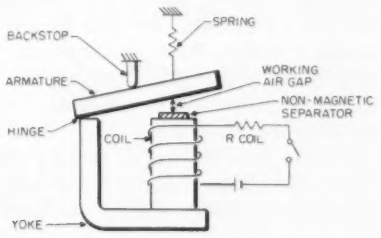
M. J. KELLY J. E. WALLACE

IN AUTOMATIC DATA-PROCESSING MACHINES many forms of electromagnetic devices are used. Since the current trend is to higher speed machines, the empirical method of electromagnetic design is no longer adequate.

Mathematical calculation of the operating characteristics of electromagnetic devices, such as relays, has been a difficult laborious task because of the implicit and nonlinear relationships of the variables. By making use of a large-scale digital computer such as the International Business Machines Corporation's (IBM) Model *650* magnetic-drum calculator, the flux, current, armature displacement, etc., may be computed as a function of time. A complete solution may be obtained in a few minutes.

The method of solution requires that each variable be described mathematically as accurately as possible. To do this, certain approximations for magnetization curves, mechanical work, and other variables must be made. The magnetization curves are approximated by a hyperbolic function, as suggested by Froelich.[1] The magnetic reluctance is calculated by the method outlined by Roters[2] and refined by Wagar and Peek.[3] The final result will not be exact, but will be within the normal range of physical variations encountered in a model. The results have been checked against experimental data obtained from closely measured laboratory models with a high degree of accuracy. The utility of this method is the ability to run a large number of solutions with a minimum of human effort. As the parameters of the magnet are varied, the approach to the optimum operating characteristics may be analyzed and additional direction given to the design.

Fig. 1. Diagram of simple 2-leg magnet.



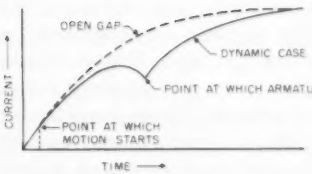




Fig. 2. Current vs time curve—dynamic condition.

The method of solution is extended to cover the three basic types of nonpolarized magnet structures; these are the 2-leg, 3-leg, and flat E-shape cores. Fig. 1 shows the elements of a simple 2-leg magnet. The mechanical equation for the system, if friction is neglected, is

$$M\frac{d^2S}{dt^2}+KS+F_0=F(t)$$

Driving force $F(t)$ is a function of the magnitude of the magnetic flux $\phi$, which is also a function of time

$$\phi=\int\frac{E-Ri}{N}dt$$

Electrical energy absorbed by the system is

$$\mathrm{E}_e=\int eidt$$

where $e=N\,d\phi/dt$

Mechanical energy extracted from the system is

$$\mathrm{E}_m=\int MVdv+\int KSds+\int Fds$$

It follows that the instantaneous value of the energy in the magnet must be

$$\mathrm{E}_f=\mathrm{E}_e-\mathrm{E}_m$$

The term $\mathrm{E}_f$ may be evaluated and solved for the instantaneous current. It then follows that flux, armature velocity, etc., may be calculated by numerical methods. An iterative procedure will result in the complete solution of the system characteristics.

Fig. 2 shows the form of the current rise with the armature blocked open and when allowed to move. When the magnet yoke consists of low-resistivity material, the measured current is usually greater than the calculated current at a given instant in time. This difference is attributed to the additional current required to sustain the eddy currents in the magnet. However, the armature displacement, velocity, etc., agree closely with measured values, even though the discrepancy in current exists. The method of calculation does not include the effects of eddy currents. Several electromagnetic devices have been designed by means of this technique, giving a high degree of optimization; also some existing units having been redesigned with a marked improvement in performance and reliability.

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# Soviet Capacity Will Not Provide for Industrial Load Growth by 1960

JOHN P. HARDT

**According to the Soviet paper, Pravda, "Electrification is the basic problem in the economic development of the country." The attainment of the 1960 production levels, in accordance with the sixth Five-Year Plan, depends upon the planned expansion of the electric power industry, as described.**

IN 1960, the Union of Soviet Socialist Republics' (USSR) production will come closer to comparable levels with the United States' industry than at any time in history, if the sixth Five-Year Plan adopted in Moscow at the 20th Party Congress this February is fulfilled. Attainment of these 1960 production levels hinges upon the planned expansion of the Soviet electric power industry, for the necessary increases in industrial labor productivity depend on a vastly increased electric power supply per industrial worker. Georgi Malenkov, ex-Premier and Minister of the Electric Power Industry, specifically sets the needed growth in industrial labor productivity from 1956 to 1960 at 50 per cent. To bring about this improvement, Malenkov stated that 65 per cent more electric power must be available for each industrial worker in 1960.

The improvement in the level of industrial labor productivity per man-hour is particularly important for the sixth Five-Year Plan, as pointed out by Premier Bulganin recently, because of the current shortage of industrial labor. A large influx of labor from the countryside will not be possible during this Plan period, presumably because of the crisis in Soviet agricultural production.

A provision for much more industrial drive, powered by electricity—that electrification of industry referred to by Malenkov—is crucial to the increase in industrial labor productivity. The crux of the electric power supply problem for Soviet industry is the question of whether sufficient dependable capacity, plus adequate reserves, can be provided in all the major industrial regions.

Recent disclosures in the Soviet press indicate that the planned increase in the supply of electric power for Soviet industrial workers, with its attendant implications for the economic struggle between the Soviet and United States economies, will not be forthcoming in 1960. Three reasons for this Plan failure in the Soviet electric power industry will be presented in this article: (1) The 42 million kw of new capacity scheduled, as shown in Table I, will not be installed by 1960. (2) Even if the 320 billion kwhr of electricity are generated according to plans in 1960, the military-oriented industrial functions of Soviet industry, like atomic energy production, will continue to expand their relative portion of the total electric power supply at the expense of the portion allocated to industrial drive. (3) Shortages of dependable capacity and inadequate reserve margins will continue to load to industrial power shortages during peak periods, even in those regions where new stations are constructed on schedule.

## AMBITIOUS PROGRAM FOR 1960

STATION CONSTRUCTION during the new Plan period represents an unusually ambitious program for capacity expansion, as indicated in Table I, and one which is unlikely to be met.

*No Five-Year Plan targets have been reached to date.* As shown in Table I, the new capacity scheduled for the peacetime Plan periods from 1928 to 1955 have fallen short from 12 per cent for the fifth Five-Year Plan to 45 per cent for the second Five-Year Plan. An important aspect of the Soviet planning procedure is an attempt to "balance the estimates," that is, equate the supply and demand for goods, throughout the economy in any given Plan. As a result, it can only be concluded that the failure to meet the planned levels in capacity installation resulted in shortages of power, particularly during periods of maximum demand.

*Drastic increase in yearly rate of capacity installation scheduled.* As a basis for the belief that in 1960, for the first time, all the capacity scheduled would be installed, one is tempted to point to the fact that the last Five-Year Plan ending in 1955 came closer to fulfillment than any of the previous ones. This view might be warranted if it were not for the tremendous increase in the planned yearly rate of capacity installation in the new Plan to a level of over 8 million kw per year, almost triple the highest previous rate. This large increase was dictated in part by a desire to attain the United States level of some 10 to 13 million kw per year according to Aleksandr Vinter, one of the leading Soviet electric power authorities.

Also, indicative of the ambition of the Plan for 1960 is the fact that the Plan was recently drastically revised upward. The long-run Soviet goals for 1960, set by Stalin in 1946 and reiterated by Premier Bulganin in July 1955, called for 60 million kw or about 18 million kw less than the Plans announced in January 1956. The increase alone in this revision of plan almost equals the total installed capacity in 1950. This upward revision transformed an ambitious program representing a yearly rate twice the previous high,

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to a program that will not be maintainable according to present indications.

*Hydro construction projects still a Soviet headache.* The hydroelectric capacity installed in the sixth Five-Year Plan is scheduled to increase from 3.7 to 9.9 million kw. During the postwar period, the extended construction times required by hydroelectric projects have been largely responsible for the Plan failure for capacity as a whole. In the first postwar Plan period, as little as 30 per cent of the scheduled hydroelectric capacity was installed by 1950. During the second postwar Plan period, terminating in 1955, the percentage of fulfillment was still only 43 per cent for the hydroelectric projects.

Even the Kuibyshev station on the Volga fell behind schedule. This project, described when undertaken as the largest in the world in terms of capacity at 2.1 million kw must have had a high priority. Its retarded construction has not been ignored in the Soviet press. Originally, the entire project was to be completed by 1955. As late as August 1955, it was announced in *Pravda* that the first power would be available on December 20, 1955. In February 1956, Soviet writers indicated that the completed first section, representing a small portion of the total capacity, is operating. The difficulties of such an important project illustrate only a small number of the problems encountered in less publicized hydroelectric projects.

Undismayed by the problems faced by the construction of such projects as the Kuibyshev station on the Volga, Soviet planners have announced even more grandiose plans for new stations in the Siberian sections, as indicated in the map. Many of the problems that arose to delay the completion of the Kuibyshev station—late equipment deliveries, faulty construction equipment, poor weather, etc.—present even more formidable challenges to Soviet builders in the eastern regions. Where will the equipment for the Irkutsk and Bratsk stations near Lake Baikal be made? Will the equipment be constructed in the Leningrad factories for transport over 3,000 miles? Moreover, how can the Irkutsk station be constructed at a more rapid rate than the Kuibyshev station, as is planned, with more adverse weather problems to combat?

Even if all the hydroelectric stations were operating by 1960, as scheduled, the share of hydro capacity in the total capacity in the Soviet electric power industry will remain at its 1955 level of about 11 to 12 per cent (about 18 per cent of the total kwhr generated). This would not have been the case if the old target of 60 million kw for 1960 were still in force. But the increased capacity requirements in the new Plan announced in January 1956 were apparently entirely represented by either steam or atomic stations—about 16 million in steam stations and from 2.0 to 2.5 millon kw in atomic stations. As the large hydroelectric stations are expected to take at least 5 years in construction, new stations scheduled in late 1955 could not be expected to be in operation by 1960, especially with the poor record of hydroelectric projects in the Soviet Union. This underlines the continuing predominance of steam stations in the Soviet electric power industry.

*Steam projects face new problems for 1960.* For the first time since World War II, the completion of steam stations may provide a bottleneck in Soviet electrification. The prewar problem in steam station construction was the shortage of equipment. As Bulganin stated in February 1956, "The machine-building industry is faced with a decidedly difficult task in making the electric equipment for steam stations."

The production of turbines, for example, is to be increased by 2.5 times from 1956 to 1960. That turbine production is to supply the equipment for the expansion of the annual rate of steam capacity installation by 2.7 times, from a yearly rate of 2.8 million kw in the fifth to 7.2 million kw during the sixth Five-Year Plan. As a good part of the increased steam capacity dates from 6 months or less before the start of the Plan period, and as the construction of new electric machine-building plants takes considerable time, it seems fair to assume electric equipment for steam stations may again be a bottleneck for Soviet electrification.

In addition, new models are being introduced in steam equipment for the new Plan period. The steam pressures and temperatures in the new boiler equipment are to be raised to 1,985 pounds per square inch (psi) and 995 to 1,000 C, from a previous high for standard equipment of 1,324 psi and 932 C. The average capacity of the new turbogenerator plants is to be raised from 25 and 50 thousand kw to 100 and 200 thousand kw. The construction of the new factories for the latest type equipment represents a special problem, as emphasized by Maxim Saburov, chairman of the State Planning Commission.

Moreover, as in the case of the hydroelectric stations, many of the new stations will be constructed in the eastern regions. If, as in the past, the new electric machinery is constructed in the traditional sources like the Leningrad factory, "Electrosil," then bottlenecks in supply, occasioned

**Table I. Capacity Installed in the Soviet Electric Power Industry, Million Kw**

| 5-Year Plan Periods | Total at End of Plan Period | New Capacity Added in Plan Period | | Per Cent Fulfillment | Yearly Rate of Actual Installation |
|---|---|---|---|---|---|
| | | Actual | Planned | | |
| First (1928–1932) | 4.7 | 2.8 | 3.6–4.8 | 70–78 | 0.7 |
| Second (1933–1937) | 8.1 | 3.4 | 6.2 | 55 | 0.68 |
| Third* (1938–1945) | 10.7 | 2.6 | 7.1(1942) | 37 | 0.32 |
| Fourth (1946–1950) | 19.2 | 8.5 | 11.7 | 73 | 1.7 |
| Fifth (1951–1955) | 35.0 | 15.8 | 19.2 | 82 | 3.16 |
| Sixth (1956–1960) | 77.0(plan) | | 42.0 | | 8.4 |

*Wartime loss 5 million kw.

by slow construction of machinery and compounded by transportation delays, will cause increases in steam capacity to fall behind the level scheduled for 1960.

In expanding atomic power capacity, the Soviets have stolen the march on the British. The British had taken the lead in peaceful uses of the atom for generating electric power with plans for some 1.5 million kw by 1955. Now the USSR proposes to have 2.0 to 2.5 million kw installed by 1960. If these stations are installed in inaccessible eastern regions, the construction problems may be as difficult for those stations as for the hydro and steam stations.

## LOAD GROWTH VS EXPANSION OF OUTPUT

EVEN if the capacity expansion plans are not fulfilled, the goal of 320 billion kwhr for electric power generation may be met in 1960. Of course, completion of output plans would not mean that the maximum demands in Soviet industry were met in each industrial region, as would be required to avoid power shortages. However, assuming the total output figures were an adequate measure of fulfillment of the industrial demand for electric power, there would still be a deficiency of power needed for mechanization of industrial labor. In the allocation of the total electric power production of the Soviet electric power industry, the portion consumed for industrial drive is likely to decrease as the allotment to industrial processing increases during the sixth Five-Year Plan. Moreover, there is little chance for compensation of that relative loss in total power supply from nonindustrial consumers, as industry already receives the preponderance of the electric power distributed, as indicated in Table II.

To those schooled in the electric power industry of the United States, the allocation problems in the Soviet Union may seem somewhat foreign. There has never been a sales problem in the Soviet electric power industry. Instead of sales considerations, there have been constant difficulties in supplying sufficient power to the preferred customer—Soviet industry.

*Industrial mechanization or atomic energy.* The share of electric power allocated to processing in industries has been increasing at the expense of the industrial share used to provide driving power for industrial machines, as shown in Table II. The demand for electric power for industrial processing in the Soviet chemical, nonferrous-metal, iron and steel, machinery, and, above all, for the rapidly expanding atomic-energy industries is increasing at least as rapidly as in the past. If the consumption of electric power for industrial processing continues to increase at the expense of power for industrial drive, can the Soviet plans for mechanization during the new Plan be met? The answer is no!

They cannot deprive industrial drive because, as Malenkov stated, 65 per cent more power per worker is necessary to bring about the needed improvement in industrial labor productivity during the sixth Five-Year Plan. On the assumption that no increase in the industrial labor force would occur, about 40 per cent of the total kwhr generated, some 126 billion kwhr, would be needed in 1960. However, as a small increase in the labor force is planned, the percentage of 45 per cent in 1955 would have to be maintained in 1960 in order to supply the workers with the necessary power.

It would be very difficult to maintain the 45 per cent level in the face of the continuing pressure for the allocation of more electricity for industrial processing. By retaining the 1955 share of 22 per cent of total electric power for industrial processing in 1960, the electricity available for these uses in industry would be increased from 37.4 to 70.4 billion kwhr. The expansion of the output of the products in the Soviet chemical, nonferrous-metal, iron and steel, and machine-building industries—large consumers of electricity for processing—is great for this new Plan period. Even with constant levels of technology, these industries cannot be expected to use a smaller share of the total power supply in 1960. However, the key problem is that of supplying the rapidly expanding demands of the atomic-energy industry.

It might be argued, as a first approximation, that USSR production of atomic energy for military uses would tend to equal that of the United States. It is already known that the peaceful use of atomic energy for electric power generation is scheduled to exceed that in the United States. However, the thesis of equality in the absolute amount of electric power consumption for military production of atomic energy in the Soviet Union and the United States seems hardly tenable. The Atomic Energy Commission (AEC) in the United States currently is consuming at the rate of 9.5 per cent, the total electric power generated in the United States, or a total of about 62.3 billion kwhr in 1955. This is almost twice the total electric power consumed for all industrial processing in the Soviet Union in the same year. Assuming 800 billion kwhr were generated in the United States in 1960 (Paley Commission estimate),* 9.5 per cent, or 76 billion kwhr would still be much above the level possible in the USSR. That level of consumption would represent one quarter of the entire Soviet generation planned for 1960. Also, there is every reason to assume that the percentage of total electric power consumed by the AEC will continue to increase in the years to

**Table II. Allocation of Electric Power in the USSR, Selected Years, (in Per Cent of Total Kwhr Generated)**

| Sector | 1928 | 1940 | 1950 | 1955 | 1960 (Plan) |
|---|---|---|---|---|---|
| Industry | 68.4 | 67.4 | 69.0 | 69 | 69.0 |
| of which: | | | | | |
| Drive | 65.8 | 53.9 | 47.7 | 45 | |
| Processing | 1.3 | 12.1 | 19.9 | 22 | |
| Lighting | 1.3 | 1.4 | 1.4 | 2 | |
| Municipal services | 19.2 | 13.5 | 11.4 | 11 | 10.2 |
| Transportation | 2.0 | 3.5 | 3.9 | 4 | 4.7 |
| Agriculture | 0.7 | 0.9 | 1.0 | 1 | 1.1 |
| Station needs and transmission loss | 9.7 | 14.7 | 14.7 | 15 | 15.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*A report to the President by the President's Materials Policy Commission, W. Paley, Chairman, 1952.

come in some manner similar to the past increases. In short, the Soviet Union is not likely to be able to allocate as much power to atomic energy production as is the United States in 1960. But, at the same time, there will surely be great pressure to raise the allotment as high as possible. If this means a significant increase in the share of total electric power supply used for processing in industry, it will have to be taken largely from the share used to provide industrial drive. This would mean the growth in labor productivity planned for Soviet industry in the sixth Five-Year Plan would be imperiled.

*Industrial share cannot be expanded.* Actually, the availability of electric power for industry at peak periods, not total generation, is the key to industrial production. Power shortages at peaks have been a consistent problem in the Soviet electric power industry. Even though, in the allocation of electric power, industrial drive has been given high priority during periods of maximum demand, power shortages have often held up industrial production. These shortages have resulted in spite of a very cavalier use of nonindustrial power supplies as "reserves" for industry. A typical example is a report from a newspaper in Baku, one of the larger cities in the southern USSR: "In evenings it is frequently impossible to read or prepare homework. People cannot listen to their radios and electric appliances are useless. People are obliged to burn kerosene lamps and even candles. Every day after 6 or 7 in the evenings the voltage in the network drops and is especially bad on Saturdays. Sometimes the current is cut off for hours without any warning . . . The current is so weak in the street lights that the streets are scarcely illuminated." (*Baku Rabochi* [Baku Worker], February 26, 1954).

Electric power for transportation and agriculture have received no better treatment than municipal services in power allocation during periods of maximum demand from industry. Thus, the allocation of additional electric power to industrial drive from nonindustrial consumers is not likely.

*Soviet will lag farther behind the United States industrial technology.* In 1955, an estimated 3.9 kwhr of electric energy was consumed per man-hour worked in Soviet industry. The electric power supply per worker would be increased to about 6.4 kwhr per man-hour in 1960, if the electrification plans for Soviet industry were fulfilled.

According to the Paley Commission estimates, the consumption of electric energy in manufacturing industries in the United States was to increase from 6.27 to 18.0 kwhr per man-hour from 1950 to 1975. Assuming that increase were at a constant absolute yearly rate, the power supply per man-hour would be 8.6 and 13.3 kwhr per man-hour in 1955 and 1960, respectively.

The absolute advantage of workers in manufacturing industries in the United States over Soviet industrial workers in power supply per man-hour would thus be increased from 4.7 kwhr in 1955 (8.6 minus 3.9) to 6.9 kwhr in 1960 (13.3 minus 6.4).

Taking the power supply in industry per man-hour as a fair gage of technological levels, as the Soviet leaders do, it can be concluded that even by completion of the electrification plans for Soviet industry by 1960, the level of technology in Soviet industry would fall farther behind the United States level in 1960 than it was in 1955.

## CAPACITY PLUS RESERVES NOT ADEQUATE

POWER SHORTAGES for industrial supply have resulted from the gap between installed and available capacity. Although there were only 300 thousand kw of nonoperating capacity in 1954 out of the total 32.6 million kw, the concentration of the nonoperating capacity in a few regions has created serious problems of regional power deficiencies.

*Forced outages and long repair times.* The high rate of forced outage or breakdowns and the subsequent long repair times for equipment have been continuing problems in the Soviet electric power industry. Corrective actions have ranged from on-the-job-training for electric power workers to "wrecking trials" with serious consequences for those found responsible for the breakdowns. Although breakdowns have been blamed on the station personnel, it is clear that poor quality equipment has played a significant role. In 1954, for example, a 1,000-thousand-kw generator made in Leningrad was found to have serious defects in the insulation of the rotor winding. This was one of many instances of poor quality equipment recently reported in the Soviet press.

In lieu of equipment tests, the installed equipment had often been tested in operation. This period was referred to in Soviet technical publications as that of "children's diseases," that is, the equipment would normally go through a period of breakdowns as children go through a period of mumps, measles, and the like.

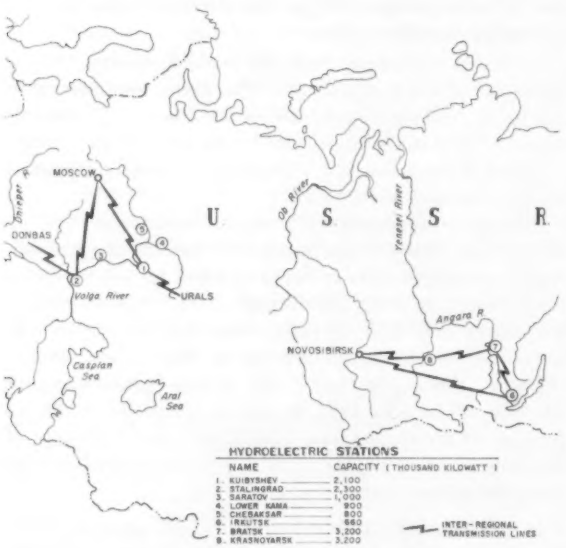
Adding to the problem of frequent breakdowns were the long periods that the equipment remained out of operation either awaiting repairs or being repaired for a second and third time. In 1950, an average of 18.5 operating days for boilers and 15.9 operating days for turbogenerators were lost, according to reports in *Elektricheskie Stantsii* (Electric Power Stations), the Soviet counterpart of *Electrical World*. In 1954, it was reported that about 15 per cent of the repairs were incomplete, and 2 per cent of the boilers and turbogenerators had to be repaired at least twice during that year.

*Hydroelectric deficiency.* Adequate water often has not been available to operate the installed hydroelectric capacity in the Soviet electric power industry. Because of the concentration of hydrocapacity in a small number of systems and the wide variations in water flow, serious regional shortages have developed during low-water years.

The primitive method of estimating the water supply for Soviet hydroelectric stations has largely accounted for the problems of hydro deficiency. In 1955, it was acknowledged that the Central Forecasting Institute avoids long-range predictions on the amount of water to flow in the Soviet rivers, and that even the predictions of the Institute for a month in advance are not precise. For planning purposes, it reportedly is Soviet policy to use a figure representing 75 per cent of the existing water supply in a river during the years the plans are being drawn up. The trouble with

that practice, according to an editorial printed in the Soviet publication *Gidrotekhnicheskie Stroitel'stvo* (Hydroelectric Construction), is that in low-water years the actual water available may fall to 45 per cent of the "average" water supply level. This could mean that if a "run-of-the-river" hydroelectric station with a capacity of about 100,000 kw could use all of the available flow during a given year, estimates for the following years would be made on the basis of an operating capacity for that station of 75,000 kw, but the actual operating capacity might fall to as low as 45,000 kw in low-water years.[1] Such a station would thus be operating only 60 per cent of its rated capacity.

*Reserve margins small.* The official policy has been to retain reserve margins of at least 10 per cent in the systems in the industrial regions of the Soviet Union, in order to maintain a continuous power supply for Soviet industry. This goal has been repeated in every Plan since the problem was discussed at length during the 18th Party Congress in 1939, but the targets for reserve margins have not been met. Again, in the sixth Five-Year Plan, a growth of electric power capacity more rapid than the growth in industrial production is called for to ensure the creation




of adequate reserves. If the capacity installation plans are not fulfilled, the reserves will again be less than planned.

It should be noted that 10-per-cent reserve margins are rather small. Margins of 20 per cent have been referred to as less than adequate in the United States. The Soviet margins are particularly small in view of the gap existing in many systems between installed and operating capacity.

*Bulk transfers between regions will not be possible by 1960.* Regional power shortages cannot be relieved, in most cases, in the USSR, because transmission lines needed for bulk transfers of power have not been available. A major effort is planned for the sixth Five-Year Plan to interconnect the major regions of European Russia. The hydroelectric stations at Kuibyshev and Stalingrad on the Volga river are to be the focal points of this network. Major lines are under construction from these Volga stations to Moscow. The Plan, likewise calls for lines from the Volga stations to the Ukraine, and the Urals. There are also to be lines connecting the regions around Lake Baikal with west Siberia, as shown on the map. By 1960, the Unified European High Voltage Network is scheduled to include 28 million kw—about a third of the total installed capacity planned for that year.

However, construction of the first major lines from the Volga stations to Moscow have fallen behind schedule. July 1, 1955, was the date set for the first current to flow through the line from Moscow to Kuibyshev. This goal was not met and it is not clear from Soviet reports whether or not the line has been finished to date.

In addition, a large share of the hydroelectric and steam capacity within some regional systems has been nonoperating because the transmission lines needed to carry the electric power to the load centers have not been available. Particular attention has recently been devoted to the shortage of electric power resulting from the unfulfilled network construction plans in the Ural Mountains. It was reported that in the year 1951 there was 1.75 km of new line per thousand kw of new capacity actually installed. A shortage of power developed in 1954 because the ratio of new line per 1,000 kw fell to 0.79. In addition to actual shortages in new industrial areas, the existing lines were overloaded and the losses in networks were very large. The Serov-Srednie Ural line had power losses up to 26 per cent. This meant a loss above the expected losses in transmission of over 1 million kwhr a day, according to Soviet reports.

In the recent relaxation of the United States controls on the Soviet purchases of "hard goods," the principal item purchased, according to the Senate testimony of John Hollister, the United States aid director, was copper wire. This information may point up one of the serious current bottlenecks in the construction of transmission lines in the Soviet Union. The fact that copper wire was an item which held up completion of Soviet transmission lines in the prewar period tends to corroborate this impression.

## SOVIET ELECTRIC POWER INDUSTRY ON THE SPOT

In the sixth Five-Year Plan, the USSR electric power industry has been given a difficult, probably impossible, task. Soviet leaders selected this "hot spot" for the deposed Premier Georgi Malenkov. In Malenkov's words the problem is succinctly stated, "The struggle for higher labor productivity is most important in our world economic struggle with capitalist countries . . . The measure and most important factor in the growth of labor productivity is the electric power supply of labor . . ."

Even before the sixth Five-Year Plan was ratified, the chairman of the State Planning Commission, Maxim Saburov, singled out the Ministry of Electric Power Stations for criticism. Minister Malenkov and his Ministry may be in for more criticism before the end of the Plan period in 1960.

# Signals from Switched Ferroelectric Memory Capacitors

C. F. PULVARI  G. E. McDUFFIE, JR.

THE PURPOSE of this article is to discuss the output signals from switched- and unswitched-ferroelectric storage capacitors, to treat the storage element as a circuit element by the introduction of an equivalent circuit, and to present methods by which the inherent signal-to-noise ratio can be improved.

The electrostatic hysteresis loop describes the microscopic behavior of ferroelectrics and shows that reversibility of polarization by an applied signal is the real criterion of ferroelectric behavior. For memory applications, a nearly rectangular hysteresis loop is desired. Fig. 1 shows the basic circuit of a single ferroelectric memory flip-flop and associated current waveforms. $C_s$ denotes the storage capacitor; the load, which may take various forms, is here shown as a resistance. Assume that the $+P_r$ point on the hysteresis loop corresponds to a binary "zero" and that the $-P_r$ point corresponds to a binary "one." When destructive readout is used and the storage condenser stores a "one," a positive readout pulse will cause a switching of polarization and a large current will flow through the load; if the storage capacitor stores a "zero," no switching will occur and only a small load current will be produced. The ratio of signal, when switching occurs, to signal, when no switching occurs, is called the signal-to-noise ratio.

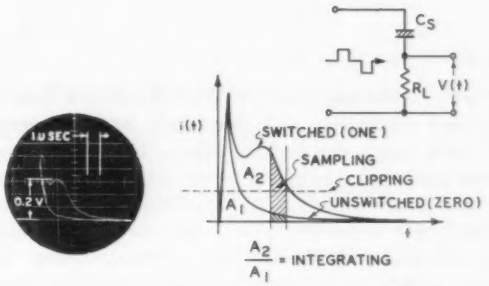



Fig. 1. Transients of a resistive load. $R_L = 220$ ohms.

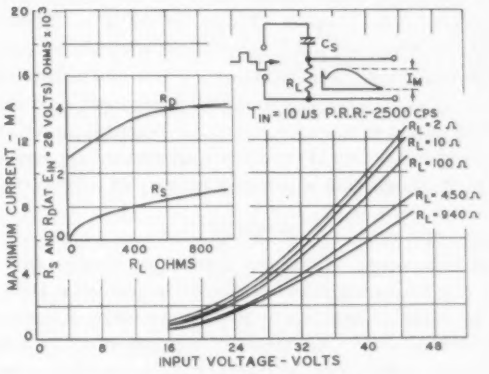



Fig. 2. Dynamic switching resistance curves.

During switching, the storage capacitor behaves like a resistance. Fig. 2 shows a family of curves obtained by plotting the maximum switched current as a function of the input pulse voltage using different resistive loads. Dynamic switching resistance $R_D$ is defined as the reciprocal of the slope of these curves. The peak power supplied to the capacitor during switching is the product of the maximum current and input voltage and can be calculated from these curves for various values of resistive load. This family of curves also shows that a current-type equivalent source is best suited for representing the storage element during switching. For calculation purposes a satisfactory equivalent circuit consists of a current generator having a current

$$i(t) = \alpha I_m t e^{-\frac{t^2}{4a}}$$

paralleled by a resistance $R_S$. $I_m$, $a$, and $\alpha$ can be calculated from the applied switching field, the area of the capacitor, and $P_r$; $R_s$ is calculated from the family of dynamic switching resistance curves. This equivalent circuit may be used for calculating the output voltage from various types of load impedances.

The reading modes for ferroelectric storage capacitors may be grouped in two general classes: destructive and nondestructive. In destructive readout, the inherent signal-to-noise ratio may be improved by amplitude, time, or frequency sampling. Amplitude sampling is accomplished by establishing a fixed clipping level, above which the output signal rises when switching occurs. Time sampling consists of sampling the output signals for a short period, sometime after the start of the readout pulse. Frequency sampling employs a filter network, which separates low-frequency components of the switched signal from the relatively high-frequency components of the unswitched signal. The choice of load impedance and sampling method is determined by desired access time and storage capacitor configuration.

Nondestructive readout may be accomplished by driving the storage capacitor ultrasonically, by using two different high-frequency signals or by using crossed electric fields; in each case, the state of the capacitor is determined by a 180 degree phase difference.

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# Basic Colorimetry for Color Television

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THE CHROMATICITY DIAGRAM is a basic tool used extensively and universally in the science of colorimetry, the study of color. In order to provide a clear mental picture of the significance of every aspect of this important diagram, its derivation is accomplished graphically by means of a logical sequence of graphical constructions and projections. Such a visual concept is extremely difficult to obtain from the complicated mathematical derivation ordinarily used.

Interest in colorimetry among electronics design engineers has come about largely through the advent of color television. The purpose of this article is to utilize the graphical derivation of the chromaticity diagram as a means for providing color television picture tube and circuit design engineers with a clear understanding of basic colorimetry and its applications to television. Practical applications of the chromaticity diagram are illustrated by means of examples drawn from both monochrome and color television.

## FUNDAMENTALS

*Color Terminology.* Common experience teaches that objects can be distinguished not only by geometric form but also by color. Color can be specified in terms of luminance and chrominance. Luminance, a measure of the brightness of an object, can be specified in terms of lumens per steradian per square meter. The lumen, or unit of luminous flux, is the amount of luminous flux emitted in a unit solid angle by a light source whose average candlepower throughout the unit solid angle is one candle. Thus, a source of light having uniform candlepower in all directions of one candle would emit $4\pi$ lumens.

Without chrominance, an object would appear in shades of gray; i.e., it would appear colorless. With chrominance added to luminance, an object appears in its natural color. The full significance of chrominance is easily seen by breaking it down into its two components, namely, hue and saturation. The hue of a color corresponds to its dominant wave length. It is the redness, greenness, yellowness, etc., of an object. Saturation is a measure of the deepness or vividness of a color. A deep red object is said to have a red hue and to be 100 per cent saturated. As white light is added in increasing amounts to the red, the redness will appear lighter and lighter until the object appears pinkish. If enough white light is added, the object may appear white with only a trace of pink. Pure white means zero per cent saturation. A 50 per-cent-saturated red appears as a light red because it contains 50 per cent white light mixed with 50 per cent of fully (or 100 per-cent-saturated) red.

**In order to give design engineers a clear understanding of basic colorimetry and its applications to television, it is necessary to provide a clear mental picture of the chromaticity diagram. The highlight of this article is the derivation of this diagram by graphical constructions.**

Another commonly used term is radiance, which is a measure of the amount of light energy being radiated, in watts per steradian per square meter.

By means of a prism, white light can be resolved into its spectrum of component colors. Conversely, the component colors can be added together to form white light. In fact, if only three specific component colors, spaced far apart in the spectrum, are combined in the proper proportions, the resultant will also be white. These three component colors are called additive primaries when adding colored lights, and subtractive primaries when adding paint pigments, which is the same as subtracting colored lights. In order to be primaries, whether additive or subtractive, they must be independent, meaning that any combination of two of the primaries should not produce the third.

The addition of three primaries in various proportions will result in the reproduction of many but not all colors occurring in nature. If the number of primaries is increased beyond three, the number of reproducible colors is increased. However, most colors encountered normally in nature are reproducible very closely with three arbitrary but carefully chosen primaries. In the additive system, the additive primaries are red, blue, and green. In the subtractive system, to reproduce the same range of colors, the subtractive primaries are the complements of the additive primaries. Two additive primaries, red and blue, will form magenta, a subtractive primary which is the complement of green. Similarly, the complement of blue is yellow (red plus green), and the complement of red is cyan (blue plus green). If red, blue, and green are chosen as additive primaries, the corresponding subtractive primaries are the complements cyan, yellow, and magenta.

*Apparatus.* Simplified diagrams of two basic types of colorimetric apparatus are shown in Fig. 1. The monochromator is a device for selecting a narrow band of spectral colors by means of a prism and movable slit as shown. The colorimeter is a device for matching an unknown color with a combination of three primary colors represented by the light sources labelled *R*, *B*, and *G*. By varying the intensity of each primary light source, it is possible to match many but not all of the spectral colors. In order to match all spectral colors, it is sometimes necessary to subtract

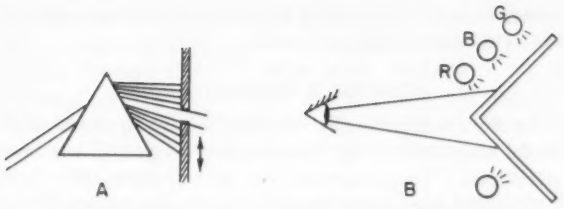


Fig. 1. Colorimetric apparatus. (A) Monochromator. (B) Colorimeter.

one or more of the primaries. This is done by placing the primary on the same side as the unknown color.

*Fundamental Rules of Colorimetry.* A set of eight rules or axioms has been developed, called the "Fundamental Rules of Colorimetry." These rules, which are the results of experiments under limited conditions of color measurement, are as follows:

1. A color match holds over a wide brightness range.
2. Brightness of a mixture equals the sum of the individual brightnesses.
3. Any color can be matched by a mixture of suitable primaries.
4. The eye cannot resolve components of a mixture of colored lights.
5. A color match can be stated as an equation.
6. Color matches obey the law of addition.
7. Color matches obey the law of subtraction.
8. Color matches obey the law of transition.

*Luminosity Curve.* Although white light is produced by a mixture of spectral colors of nearly equal intensities, our eyes do not respond to each color with equal efficiency. The response of the eye to the visual luminance or brightness of each spectral color is shown by the luminosity curve of Fig. 2. Data for this curve are obtained by adjusting the the radiances of spectrum colors in two halves of a colorimeter field until their luminances appear to be equal. Comparisons are made between a first and second spectrum color, between the second and third, and so on. The results are then reduced to show the luminance of spectrum colors of equal radiance, and are plotted in the form of the luminosity curve shown in Fig. 2. The area under this curve is proportional to the luminance produced by a given number of watts of equal-energy standard white light. The peak value of the luminosity curve, at 550 mμ (millimicrons), corresponds to 680 lumens per watt.

According to the second fundamental rule of colorimetry, the luminance of a mixture of primaries is equal to the sum of the luminances of each individual primary. This equality of luminances can be expressed as

$$L = L_r R + L_g G + L_b B \qquad (1)$$

where $L_r$, $L_g$, and $L_b$ are luminosity coefficients and $R$, $G$, and $B$ represent the unit amounts of each primary specified by unit radiance or one watt per steradian per square meter at a single wave length. The standard spectrum primaries have wave lengths of 700.0 mμ for red, 546.1 mμ for green, and 433.8 mμ for blue. A mixture of one unit amount of each primary color matches equal-energy white when the ratios of the luminosity coefficients are

$$L_r/L_g/L_b = 1/4.59/0.06 \qquad (2)$$

The unit amounts of primaries may have quite different values in lumens or watts.

Ratios of energy per unit amount of primary to produce equal-energy white are given by

$$\frac{\text{watts}}{R} \Big/ \frac{\text{watts}}{G} \Big/ \frac{\text{watts}}{B} = 65/1.5/1 \qquad (3)$$

## COLOR MIXTURE CURVES

USING THE STANDARD SPECTRUM PRIMARIES, two types of color mixture curves can be plotted for the standard observer. These color mixture curves, shown in Fig. 3, can be plotted as tristimulus values or as chromaticity co-ordinates.

*Tristimulus Values.* One basic way of specifying color completely is to use tristimulus values. A step-by-step procedure for determining tristimulus values is as follows:

1. Choose three independent primaries.
2. Place equal-energy white (reference white) on one half of a colorimeter field.
3. Adjust intensities of individual primaries until a match is obtained with reference white.
4. Define the amounts of these primaries as one unit each (they may have quite different values in watts or lumens).
5. Color match all the spectrum colors in terms of these primary units.
6. Write an equation for a match, as $C_1 = R_1(R) + G_1(G) + B_1(B)$.
7. Define quantities in parentheses as unit amounts of primaries.
8. Define coefficients as tristimulus values.
9. Designate tristimulus values for unit radiance of each spectral color by a bar, as follows: $\bar{r}$, $\bar{g}$, $\bar{b}$.
10. Plot values of $\bar{r}$, $\bar{g}$, $\bar{b}$ vs wave length of light (Fig. 3A).

According to the sixth rule of colorimetry the amount of each primary in a mixture which matches equal-energy white is equal to the sum of all the ordinates of the corre-

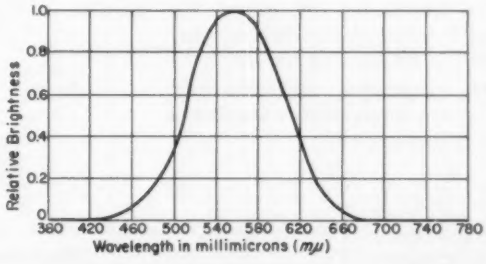


Fig. 2. Luminosity curve for standard observer. At 550 mμ, 1 watt is equivalent to 680 lumens.

Essentially full text of a conference paper presented at the AIEE Summer and Pacific General Meeting, San Francisco, Calif., June 25–29, 1956, at a session sponsored by the AIEE Committee on Television and Aural Broadcasting Systems.

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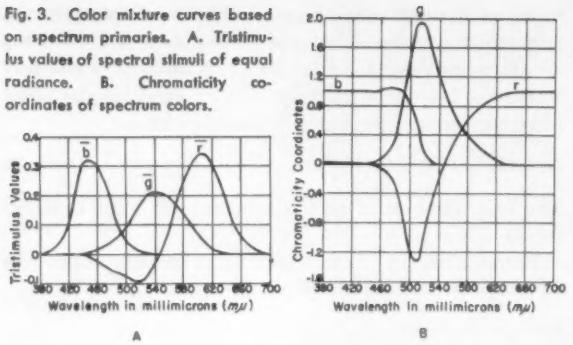


Fig. 3. Color mixture curves based on spectrum primaries. A. Tristimulus values of spectral stimuli of equal radiance. B. Chromaticity co-ordinates of spectrum colors.

sponding curve, which is the same as the area under the curve.

Since, by definition, the primary units are such as to require one unit of each primary to match equal-energy white, it follows that the total area under each of the tristimulus curves of Fig. 3A is equal to unity.

*Chromaticity Co-ordinates.* A second basic way to specify color is to use a combination of chromaticity co-ordinates and luminance. Chromaticity co-ordinates are defined as follows:

$$r=\frac{R}{R+G+B} \tag{4}$$

$$g=\frac{G}{R+G+B} \tag{5}$$

$$b=\frac{B}{R+G+B} \tag{6}$$

Here the chromaticity co-ordinates are essentially a normalized form of colorimetric data. An advantage of this form is that observer differences are reduced.

Equal-energy white, or reference white, in terms of these chromaticity co-ordinates must have the values (1/3, 1/3, 1/3). Furthermore, the chromaticity coordinates of the individual red, green, and blue primaries are (1, 0, 0), (0, 1, 0), and (0, 0, 1), respectively. Finally inasmuch as

$$r+g+b=1 \tag{7}$$

or

$$b=1-(r+g) \tag{8}$$

it follows that when two chromaticity co-ordinates are known, the third is automatically known. Any color can be specified completely by three independent quantities such as any two chromaticity co-ordinates and luminance, i.e.,

$$r=\frac{R}{R+G+B} \tag{9}$$

$$g=\frac{G}{R+G+B} \tag{10}$$

$$L=L_rR+L_gG+L_bB \tag{11}$$

where $r$ and $g$ are two of the chromaticity co-ordinates and $L$ is the luminance.

## GRAPHIC REPRESENTATION

In order to specify color by graphical means, an extremely useful chart called the "chromaticity diagram" has been developed. This diagram has always been difficult to understand because of the complex mathematics inherent in its derivation. The diagram will be developed here geometrically in order to make it more easily understandable.

*Color Cube.* The fact that colors can be specified by the number of units of red, green, and blue makes it possible to set up a 3-dimensional color space with axes labelled $R$, $G$, and $B$ as shown in Fig. 4(A). Any color uniquely defines a point in such a space. Conversely, each point defines a unique color. The color cube shown indicates that equal amounts of physical primaries $R$, $G$, and $B$, will add vectorially to produce equal-energy white, labelled $W$.

Colors that can be matched physically by combinations of the physical or real primaries $R$, $G$, and $B$ will lie in the first octant, in which all co-ordinates are positive. Colors that can be matched only with one or more negative primaries will lie in other octants. Color of the same hue will lie on the same radius vector as shown in Fig. 4(B). For a given hue, the distance of these colors from the origin will be proportional to their brightness. The vector labelled $W$ represents a scale of grays which is black at the origin and white at the endpoint marked $W$.

Planes of highly saturated colors are shown shaded in Fig. 4(C). These planes are designated the *BOR*, *ROG*, and *GOB* planes. As a color point moves in from one of these planes of 100 per-cent saturation toward the *OW* vector representing white, it becomes less saturated and, at the same time, its hue changes.

The locus of all colors of a specific luminance is a plane

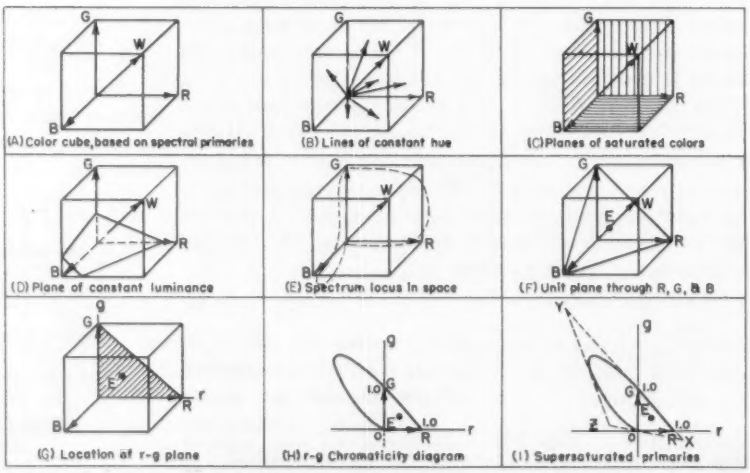
(A) Color cube, based on spectral primaries
(B) Lines of constant hue
(C) Planes of saturated colors
(D) Plane of constant luminance
(E) Spectrum locus in space
(F) Unit plane through R, G, & B
(G) Location of r-g plane
(H) r-g Chromaticity diagram
(I) Supersaturated primaries

Fig. 4. Graphical derivation of the r-g chromaticity diagram.

in color space. In fact, a family of planes, each corresponding to some value of constant luminance, can be shown cutting through the *RGB* color cube. A single plane of constant luminance is shown in Fig. 4(D). Within the color cube, only the 100 per-cent-white point can have 100 per-cent luminance, and only the origin (or physical black) can have zero luminance.

Fig. 4(E) shows a plot of the spectrum locus, represented by the dotted curve in space, which indicates the terminal points of all vectors extending from the origin and corresponding to single-wave-length spectrum colors of unit radiance. Because the dotted curve represents spectrum colors, its locus is not confined to the first octant or color cube.

Inasmuch as the direction of a color's radius vector specifies its chrominance (hue and saturation), one way of describing this direction or chrominance is to define the point at which the vector passes through some reference plane. Such a plane, called the unit plane, is shown in Fig. 4(F). The unit plane, which cuts the color cube at points (1, 0, 0), (0, 1, 0), and (0, 0, 1), is defined by

$$R+G+B=1 \qquad (12)$$

The chromaticity co-ordinates for any color automatically fall on this plane. The point *E*, located at the center of gravity of the unit plane *RGB*, represents equal-energy white. The shaded portion of Fig. 4(G) is simply the projection of the unit plane upon the rear wall or *GOR* plane of the color cube. Point E then appears at the geometrical center of the shaded triangle.

If the vectors representing the spectrum locus, the dotted curve of Fig. 4(E), are extended to intersect the unit plane (*RGB* plane) of Fig. 4(F) extended outside the color cube, the resulting locus will be a horseshoe type curve. In projecting this locus upon the rear wall of the color cube, along with the unit plane as in Fig. 4(G), the result will be a curve as shown in Fig. 4(H) which surrounds triangle *GOR*. This triangle is the same as the shaded area in Fig. 4(G) except that it is drawn to a smaller scale to accommodate the spectrum locus as shown.

Fig. 4(H) is called the *r-g* chromaticity diagram. The *R* and *G* vectors are extended as the *r* and *g* axes, respectively. By normalizing the colorimetric quantities *R* and *G* in accordance with equations 4 and 5, *r* and *g* become chromaticity co-ordinates. Only two chromaticity co-ordinates are needed to specify the chrominance of a color because the third chromaticity co-ordinate can always be found from the first two as indicated by equation 8. Thus, the *r-g* chromaticity diagram contains only chrominance information, the luminance information having been lost during the derivation of this diagram inasmuch as the unit plane constructed in Fig. 4(F) gives only the positions of the color vectors intersecting it and not their lengths. In the *r-g* chromaticity diagram of Fig. 4(H), the end-points of vectors *OR* and *OG* represent unity. Equal-energy white, shown at *E*, is located at the geometrical center of triangle *GOR*.

The chromaticity diagram of Fig. 4(H) holds for the physical primaries *R*, *G*, and *B*. If different primaries were chosen, the shapes of the tristimulus curves of Fig. 3(A) would be different and the spectral locus on the *r-g* chromaticity diagram would be different. The choice of the spectrum primaries actually used is arbitrary. Colors which are made up of mixtures of the primaries *R*, *G*, and *B* have chromaticity co-ordinates *r* and *g* located in the first quadrant of the chromaticity diagram for physical primaries, Fig. 4(H). Colors in the second quadrant of this diagram are obtainable with one or more negative primaries. All colors reproducible in nature are located on or within the horseshoe-shaped area in the first and second quadrants. Saturated spectrum colors are located on the curve. Starting at *O* this curve extends out into the second quadrant, through *G*, and into *R* where it terminates. The portion from *O* to *R* represents nonspectral colors, which do not appear in the spectrum, such as magenta, a mixture of red and blue.

## CHROMATICITY DIAGRAM

ONLY ONE CHROMATICITY DIAGRAM is needed to study all color-mixture problems, regardless of the particular primaries on which it is based. A set of primaries can be chosen arbitrarily in such a manner as to make the diagram as useful as possible. In fact, the primaries need not be physical or real primaries. They can be nonphysical or fictitious primaries such as *X*, *Y*, and *Z* in Fig. 4(I). These imaginary (or supersaturated) primaries are mathematical and do not occur in nature.

*Choice of Nonphysical Primaries.* Aside from the elimination of negative lobes and the placement of two of the new primaries along the straightest part of the spectrum locus, perhaps the most important feature of the new primaries is that two of them, *X* and *Z*, are so chosen that they have zero luminance in order that the remaining one, *Y*, will contain all the luminance information. Referring to the constant luminance plane illustrated in Fig. 4(D), and recalling that the zero luminance plane is parallel to this plane but passes through the origin, the intersection of the zero luminance plane with the *RG* plane can be

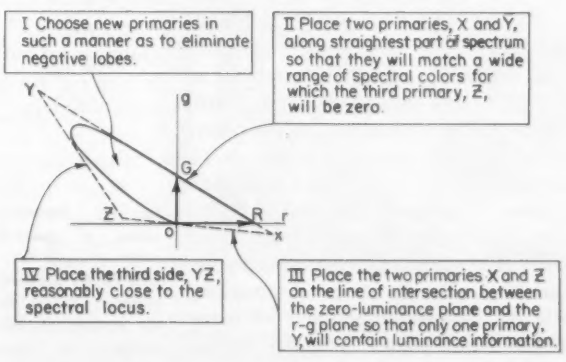
I Choose new primaries in such a manner as to eliminate negative lobes.
II Place two primaries, X and Y, along straightest part of spectrum so that they will match a wide range of spectral colors for which the third primary, Z, will be zero.
Y
g
G
Z
R
r
O
x
IV Place the third side, YZ, reasonably close to the spectral locus.
III Place the two primaries X and Z on the line of intersection between the zero-luminance plane and the r-g plane so that only one primary, Y, will contain luminance information.

**Fig. 5. First step in transformation of *r-g* chromaticity diagram to *x-y* chromaticity diagram.**

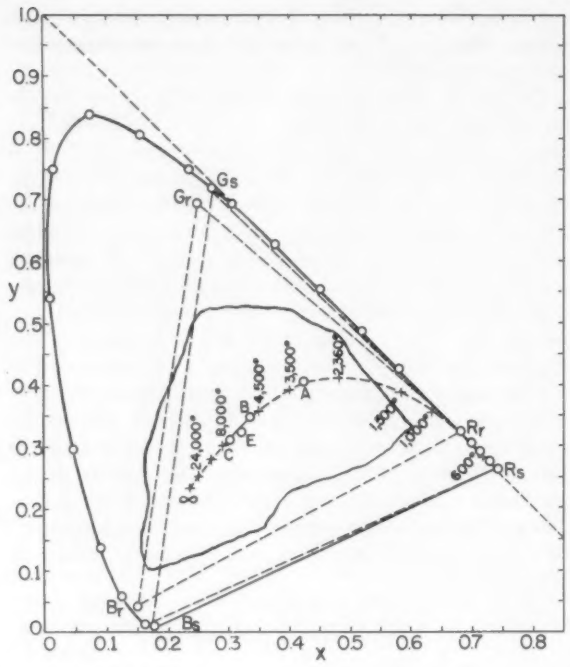


Fig. 6. The *x-y* chromaticity diagram. The ICI nonphysical primaries are $R_s$, $G_s$, and $B_s$. Color television receiver primaries are $R_r$, $G_r$, and $B_r$. The jagged solid line represents the locus of extreme purities of pigments, dyes, and inks for illuminant C. The dashed curve represents the locus of radiation from a black body at various temperatures. Points *A*, *B*, and C represent the chromaticity of the ICI illuminants. Equal-energy white is located at *E*.

visualized easily. This line of intersection is the line of zero luminance.

*Transformation of Co-ordinates.* After the *X*, *Y*, and *Z* nonphysical primaries are selected, the next step in the derivation of the chromaticity diagram in its final form is to convert the *XZY* triangle into a right triangle in the first quadrant. In other words, the next step is to transform the chromaticity diagram from the *r* and *g* chromaticity co-ordinate axes to the *x* and *y* chromaticity co-ordinate axes which are extensions of the sides *ZX* and *ZY*, respectively (Fig. 5).

Assuming that equal-energy white is reference white for both the *RGB* and *XZY* systems, the point marked W is common to both. It is the terminal point in the *RGB* color cube and also in the *XYZ* color parallelepiped. Extensions of vectors *G* and *R* form the *g* and *r* chromaticity co-ordinate axes, respectively. Similarly, extensions of vectors *X* and *Y* form the *x* and *y* chromaticity co-ordinate axes. The *XOZ* plane is the zero-luminance plane, parallel to the plane of constant luminance in Fig. 4(D). The plane of 100 per-cent luminance is the parallel plane containing the end points of vectors *OY* and *OW*. Planes of constant luminance, between zero and 100 per cent, are located parallel to and between these two planes. Line *OX* is the zero luminance line for the *x-y* chromaticity diagram because it is the intersection of the *YOX* plane and the *ZOX* or zero-luminance plane. The *OW* vector, or equal energy-white, is the diagonal for both the *RGB* color cube and the *XYZ* color parallelepied.

*Chromaticity Diagram.* In order to make the chromaticity diagram more convenient to use, the *XYZ* color parallelepiped is transformed or distorted into a cube. The *RGB* color space, formerly a cube, now becomes a parallelepiped. The horseshoe-shaped spectrum locus is now in final form and the standard *x-y* chromaticity diagram is shown in the first quadrant of the *XOY* plane.

The *x-y* chromaticity diagram is redrawn in Fig. 6. Here the chromaticity co-ordinates *x* and *y* are scaled from zero to unity. Since the *x* axis has zero luminance, the *y* co-ordinates of all colors on the diagram are proportional to brightness. When *y* is unity, the brightness is 100 per cent relative to reference white. This diagram is usually called the chromaticity diagram and is sometimes referred to as the ICI (International Commission on Illumination) or the CIE (Commission Internationale de l'Eclairage) diagram. In the ICI system the red, green, and blue physical primaries are monochromatic light sources having wave lengths of 700, 546.1, and 435.8 mμ, respectively. The green and blue primaries, represented by $G_s$ and $B_s$ in Fig. 6, are prominent lines in the spectrum of the mercury arc and hence are readily and precisely reproducible. The wave length of the red primary $R_s$ is not critical because the hue of this portion of the spectrum remains essentially constant over a wide range. All colors located within the triangle $R_sG_sB_s$ are reproducible with these physical primaries. Color television primaries are represented by $R_r$, $G_r$, and $B_r$. Therefore, all colors which are reproducible by a color television system are contained within the triangle $R_rG_rB_r$. The jagged solid curve on the chromaticity diagram of Fig. 6 bounds an area containing all colors reproducible with pigments, dyes, and inks which are illuminated with illuminant *C*.

The chromaticity of radiation from a black body at various temperatures is shown in Fig. 6 by means of the dashed curve. Equal-energy white, which represents radiation of an equal amount of energy at every wave length, is designated by the point *E*. The chromaticities of various important illuminants used in practice are designated by points *A*, *B*, and *C*. Illuminant *A* is a tungsten lamp giving off incandescent light at a temperature of 2,848 degrees Kelvin. Illuminant *B*, representing noon sunlight, utilizes a lamp having the spectral quality of illuminant *A* in combination with a special filter and corresponds to a temperature of 4,800 degrees Kelvin. Illuminant *C* likewise consists of a source having the spectral quality of illuminant *A* but in combination with a different filter so as to give north sky daylight at a color temperature of 6,500 degrees Kelvin.

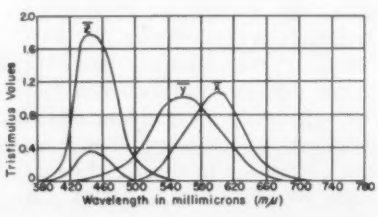


Fig. 7. Tristimulus values of spectral stimuli of equal radiance for the standard observer, based on ICI nonphysical primaries.

*Transformed Tristimulus Values.* The tristimulus values $\bar{r}$, $\bar{g}$, and $\bar{b}$ plotted in Fig. 3(A) are based on the spectrum or physical primaries $R$, $G$, and $B$. After the transformation of chromaticity co-ordinates from the physical primaries $R$, $G$, and $B$ to the nonphysical or imaginary primaries $X$, $Y$, and $Z$, however, the new tristimulus values $\bar{x}$, $\bar{y}$, and $\bar{z}$, (corresponding to the new primaries $X$, $Y$, and $Z$) appear as shown in Fig. 7. Because the $x$-$y$ chromaticity diagram lies wholly in the first quadrant of the $XY$ plane, the $\bar{x}$, $\bar{y}$, and $\bar{z}$ tristimulus values are always positive for all wave lengths. Because the $X$ and $Z$ primaries lie in the $XZ$ or zero-luminance plane, the tristimulus values $\bar{x}$ and $\bar{z}$ contain no luminance information. All the luminance information is contained in $\bar{y}$ which, therefore, is identical in shape to the luminosity curve of Fig. 2.

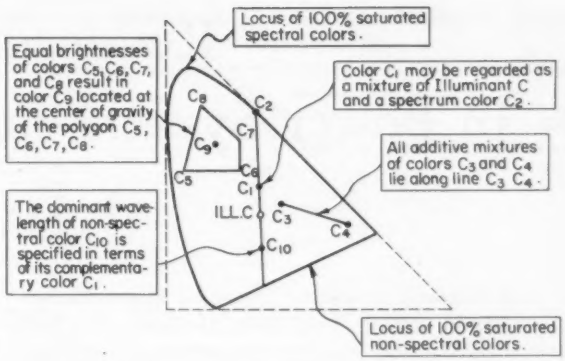
Locus of 100% saturated spectral colors.
Equal brightnesses of colors C5, C6, C7, and C8 result in color C9 located at the center of gravity of the polygon C5, C6, C7, C8.
Color C1 may be regarded as a mixture of Illuminant C and a spectrum color C2.
All additive mixtures of colors C3 and C4 lie along line C3 C4.
The dominant wavelength of non-spectral color C10 is specified in terms of its complementary color C1.
ILL.C
Locus of 100% saturated non-spectral colors.

Fig. 8. Various properties of the chromaticity diagram.

## APPLICATIONS OF CHROMATICITY DIAGRAM

*Color Specifications.* If two colors are represented by identical tristimulus values, they constitute a color match under standard conditions. However, tristimulus values do not readily indicate a difference between two colors if a difference exists. For example, if tristimulus values for two colors are specified by $X=50$, $Y=60$, $Z=40$ and by $X'=25$, $Y'=30$, $Z'=20$, respectively, the corresponding $x$ and $y$ chromaticity co-ordinates are

$$x=\frac{X}{X+Y+Z}=\frac{50}{50+60+40}=\frac{50}{150}=0.333 \tag{13}$$

$$y=\frac{Y}{X+Y+Z}=\frac{60}{50+60+40}=\frac{60}{150}=0.400 \tag{14}$$

and

$$x'=\frac{X'}{X'+Y'+Z'}=\frac{25}{25+30+20}=\frac{25}{75}=0.333 \tag{15}$$

$$y'=\frac{Y'}{X'+Y'+Z'}=\frac{30}{25+30+20}=\frac{30}{75}=0.400 \tag{16}$$

respectively. The brightness information is given by $Y=60$ per cent and $Y'=30$ per cent, which is on a relative brightness scale that represents absolute black by zero and reference white by 100 per cent. Thus, these two colors are alike in chromaticity or chrominance (hue and saturation) but the first is twice as bright as the second.

The chrominance of a color is specified by means of the $x$ and $y$ chromaticity co-ordinates on the chromaticity diagram. The luminance is specified by the $Y$ tristimulus value. Thus, three quantities specify a color completely; namely, luminance and two chromaticity co-ordinates. The chrominance of a color can be specified by hue and saturation instead of by chromaticity co-ordinates.

*Properties of the Chromaticity Diagram.* Various properties of the chromaticity diagram are summarized in Fig. 8. The horseshoe-shaped part of the chromaticity diagram represents the locus of 100 per-cent saturated spectrum colors. Along this curve there is a nonuniform scale of wave lengths of light corresponding to red at the right-hand corner, progressing through the spectrum colors yellow, green, and cyan, to blue at the left-hand corner. Moving in from a fixed point on the spectral locus toward illuminant $C$ keeps the hue (dominant wave length) constant but decreases saturation in proportion to the distance moved. The straight line connecting the curved ends of the spectrum locus represents the locus of 100 per-cent-saturated nonspectral colors (colors not appearing in the spectrum, such as magenta).

Additive mixtures of two colors $C_3$ and $C_4$ lie along the line $C_3C_4$. If $C_3$ and $C_4$ have equal brightnesses, the resulting color will lie at the midpoint of this line. Various other properties are summarized on Fig. 9, which is self-explanatory.

*Luminance Contributions of Television Primaries.* Our color television primaries have been so chosen that when illuminant $C$ is reproduced by the receiver, the green primary produces 59 per cent, the red primary 30 per cent, and the blue primary 11 per cent of the reproduced luminance. The total of these percentage luminances is 100 per cent.

## Electric Tube Production

Liquid air is used by Amperex Electronic Corp. to remove moisture from exhaust equipment which is used to produce the vacuum in electronic tubes. Liquid air is poured into a thermos flask surrounding the glass trap in which the moisture condenses.

# Reduced Insulation in Power Systems at the Higher Voltages

P. L. BELLASCHI
FELLOW AIEE

**At reduced insulation levels in high-voltage systems, consideration must be given now to switching surges and 60-cps stresses, as well as the former problems of impulse and lightning. A criteria of performance for future high-voltage system insulation design and protection is necessary, as discussed in this article.**

INSULATION PLAYS AN IMPORTANT ROLE in all system planning and design, but a proportionately greater one at the higher transmission voltages. At the higher voltages it affects the economy and performance in a larger measure; therefore, the urge to proportion the insulation to the essential requirements is greater.

In the past, problems of insulation co-ordination centered primarily in considerations of impulse or lightning protection, although designers of equipment were aware of other requirements. At the reduced insulation levels now feasible with present-day lightning arresters, additional attention must be given to switching surges and to 60-cps stresses because these are conditions of service which assume an importance equal to the impulse.

This article deals with the co-ordination of station insulation to impulse, switching, and 60 cps, for applications at the higher voltages. This is a field in which important benefits can accrue as the result of further rationalization of the insulation. At the same time, one must keep in mind the vital role insulation plays and the compelling need for maintaining a criteria of performance in future system insulation design and protection, which is commensurate with the growing concentration of power in our systems.

## PROTECTION WITH PRESENT LIGHTNING ARRESTERS

IN TABLE I, the protective levels for present lightning arresters and the impulse levels that can be protected are compared. The criteria of protection in Table I is a 5,000-ampere discharge current of wave form as defined in the standards. The discharge voltages in column 3 are the maximum for present station arresters. Although industry standards have not been established yet, these data are believed to represent available performance for present station arresters. In this illustrative example, the protected level in column 4 is based on the arrester discharge voltage in column 3, increased by 40 kv and then a margin of 25 per cent. On the basis of a more abrupt rise in the current than specified in the present arrester standards and a 10,000-ampere discharge, the margin factor of 1.25 in column 4 is reduced to about 1.10 to 1.15.

As indicated in column 5, impulse levels 10 per cent under the reduced basic impulse insulation levels (BIL) in use in present practice (column 6) can be protected with station arresters of current design. It is assumed that the present impulse-test structure in American Standards Association (ASA) and National Electrical Manufacturers Association (NEMA) apparatus standards comprising the full wave, chopped wave, and front-of-wave would be retained. Thus, were impulse protection the sole consideration, the following reduction in impulse levels generally could be effected: 550 BIL reduced to 450; 650 to 550; 750 to 650; 825 to 750; 1,050 to 900; and 1,175 to 1,050.

**Table I. BILS Protected with Present Station Lightning Arresters**

| Operating Voltage, Kv | Arrester Rating, Kv* | IR Discharge Voltage, Kv Crest at 5,000 Amperes | (IR Voltage + 40 Kv) × 1.25 | BIL's Protected | Reduced BIL's, Present Practice |
|---|---|---|---|---|---|
| 138 | 109 | 285 | 405 | 450 | 550 |
| 230 | 182 | 475 | 645 | 750 | 825 |
| 288 | 228 | 600 | 800 | 900 | 1050 |
| 345 | 264 | 695 | 920 | 1050 | 1175 |
| 460 | 362 | 990 | 1290 | 1425(1300) | 1550 |

*Solidly-grounded neutral application.

## SWITCHING SURGES CO-ORDINATION AND PROTECTION

THE RATIONALIZATION of station insulation to switching surges is probably the next most important step in co-ordination. To paraphrase the minutes of a recent meeting of the AIEE Working Group on Switching Surges, these are some of the questions that must be resolved in this industry undertaking:

1. What are representative switching surges (or a representative switching surge) in wave shape, duration, and magnitude?
2. Can demonstration of the impulse and 60 cps withstand characteristics give adequate assurance of the switching surge capability of insulation?
3. What shall be the withstand levels of station equipment insulation for switching surges?
4. What requirements should be placed in lightning arresters for the discharge of switching surges and to limit surge voltages?
5. What restrictions should be placed on switching

Full text of paper 56-732, "Reduced Insulation in Power Systems at the Higher Voltages—The Problems It Presents," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, San Francisco, Calif., June 25–29, 1956. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1956.

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apparatus and system design to limit, if necessary, the severity of switching surges?

6. How are these surges affected by system arrangement, system design and protection?

A comprehensive series of switching-surge tests has been conducted on completely assembled 138-kv (650 BIL) and 230-kv (1,050 BIL) power transformers, in addition to tests on bushings in voltage classes 46 kv to 230 kv, and the results have been reported.[1] These tests demonstrate that the withstand voltages to switching surges for oil-immersed station apparatus corresponds essentially to 80-per-cent full-wave impulse. The results of the investigation provide reasonable assurance that the 80-per-cent relationship holds for surge durations well up to 5,000 microseconds or even longer. Recently switching-surge withstand data for power transformers have also been advanced from other sources. These and the data submitted[1] are summarized in Table II. More recent investigations further confirm that the ratio of 0.80 between switching-surge and impulse withstand is adequate for oil-immersed transformer insulation.

From the foregoing, the switching-surge insulation levels for transformers corresponding to the higher voltages essentially are as follows:

| BIL | Switching-Surge Withstand, Kv |
|---|---|
| 825 | 660 |
| 900 | 720 |
| 1050 | 840 |
| 1175 | 940 |

For purposes of co-ordination and with a view to simplification in standardization, the wave form and duration of the "reference" switching surge, yet to be selected, should be established primarily from a consideration of its functional significance in relation to the insulation withstand. A duration within the limits of 3,000 to 8,000 microseconds would appear indicated. The ratio of 0.80 between switching-surge and impulse withstand strength seems valid also for the other station equipment: circuit breakers, station bus insulation, coupling capacitors, air switches, etc. It can well be that this ratio holds for practically all switching surges encountered in modern stations for systems operating with the neutral solidly grounded. However, this is a matter that still must be verified by additional studies in regard to switching surges developed in stations under varied operating conditions and, then, better established from further investigations in regard to the strength of station insulation to various types of switching surges. Additional attention also will have to be given in the future to the practical effect of rain and other surrounding conditions on the withstand strength of station bus insulation, bushings (air terminal), air switches, and to the air clearances in the station in general. In areas of growing contamination it may be inadvisable to reduce the porcelain insulation (creepage distances) below present levels.

Table III presents the maximum switching overvoltages from line to ground that can be tolerated at the terminals of station apparatus for the present reduced BIL's in order to comply with what is considered good practice. The derivation is based on a margin of 25 per cent between permissible overvoltages and withstand strength. Thus,

**Table II. Switching-Surge Levels for Oil-Immersed Station Apparatus**

| Basic Impulse Insulation Levels, BIL | Switching Surge Withstand Levels | | |
|---|---|---|---|
| | Kv* | Kv† | Kv‡ |
| 550 | 440 | 425 | 405 |
| 650 | 520 | 505 | 490 |
| 750 | 600 | 600 | 575 |
| 825 | 660 | 660 | 640 |
| 900 | 720 | 725 | 700 |
| 1050 | 840 | 845 | 815 |
| 1175 | 940 | 945 | 930 |

*Based on tests conducted on 138-kv and 230-kv power transformers and on power bushings, 46 kv to 230 kv. Tests with oscillatory switching surges of 1,000 to 4,000 microsecond period with full waves and waves chopped on crest.

†Switching-surge level equal to 1.3 times crest of transformer low-frequency test voltage. Duration 2,000 microseconds. See also reference 3 which gives levels 3 to 4 per cent lower.

‡Switching-surge duration, 3,000 microseconds.

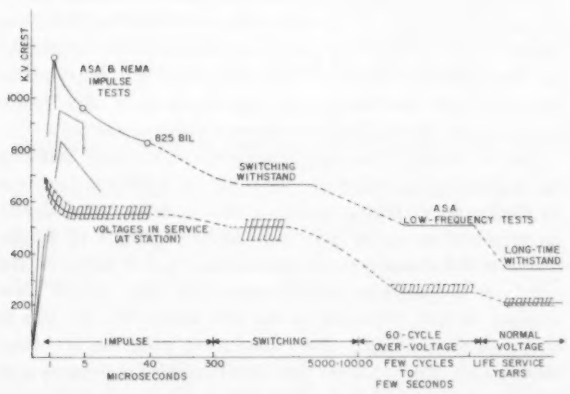


Fig. 1. Co-ordination of 230-kv 825-BIL transformer insulation to service conditions.

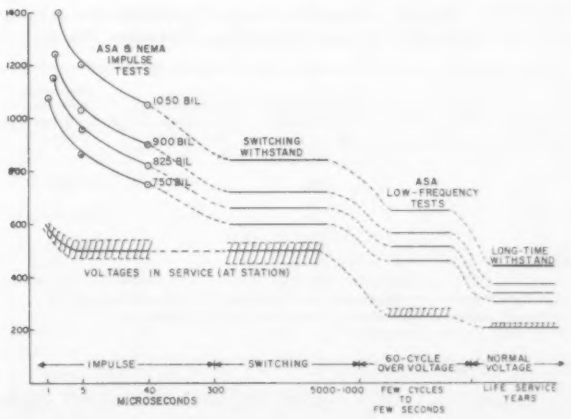


Fig. 2. Co-ordination of 230-kv transformer insulation and relative margins for 2-step reduction in BIL.

column 5 states that in the voltage classes, 345-kv to 230-kv, station insulation in which the full reduced levels are used may be subjected to switching surges not to exceed 2.5 to 2.7 times line-to-ground crest $E_{LN}$.

**Table III. Maximum Switching Surges Permissible for Reduced BIL's**

| Voltage Class* | Basic Impulse Insulation Level | Switching-Surge Withstand Level, Kv† | Switching-Surge Protective Level, Kv† | Maximum Switching Surge Permissible ($\times E_{LN}$)* |
|---|---|---|---|---|
| 242 (230) | 825 | 660 | 530 | 530/198 = 2.7 |
| 302 (287) | 1,050 | 840 | 670 | 670/248 = 2.7 |
| 362 (345) | 1,175 | 940 | 750 | 750/295 = 2.5 |

*Maximum system voltage assumed in determining switching surge permissible. (Example: $242\sqrt{2/3} = 198$; $530/198 = 2.7$)

†The switching surge protective level in column 4 equals the switching surge withstand in column 3 times 0.80 (i.e., margin between protective and withstand levels in this tabulation equals 25 per cent).

Referring again to Table III, a 10-per-cent reduction in the present BIL's in column 2 (about one class reduction), obviously would reduce the switching-surge withstand levels the same amount and, therefore, require a corresponding reduction in the permissible switching overvoltages appearing in the station; i.e., from 2.5 and 2.7 $E_{LN}$ down to 2.25 and 2.4 $E_{LN}$. Whether transient overvoltages can be limited to these lower values under all possible conditions of system and equipment operation and in all circumstances is one of the questions in insulation co-ordination and protection that has yet to be resolved. However, the possibility of attaining this goal with further advancement in the art appears promising.

With a better quantitative understanding and a firmer control of the switching-surge problem, a margin of 10 per cent between the switching-surge protective and withstand levels may be acceptable. In that event, as shown in Table IV the permissible switching-surge overvoltages corresponding to a 2-step reduction in BIL would be 2.6 to 2.75 times line-to-ground crest, comparable to the values in Table III.

**Table IV. Maximum Switching Surges Permissible for a 2-Step Reduction in BIL and 10-Per-Cent Protective Margin**

| Voltage Class* | Basic Impulse Insulation Level | Switching-Surge Withstand Level, Kv† | Switching-Surge Protective Level, Kv† | Maximum Switching Surge Permissible ($\times E_{LN}$)* |
|---|---|---|---|---|
| 242 (230) | 750 | 600 | 545 | 545/198 = 2.75 |
| 302 (287) | 900 | 720 | 654 | 654/248 = 2.65 |
| 362 (345) | 1,050 | 840 | 763 | 763/295 = 2.6 |

*Maximum system voltage assumed in determining switching surge permissible.

†Margin between protective and withstand levels equals 10 per cent.

## PROTECTION OF STATION INSULATION

THERE IS A LACK of specific technical data on the sparkover voltage and protective characteristics of lightning arresters to switching surges. Based on available published data[3] column 6 of Table V indicates that present station lightning arresters will limit switching surges to 2.4 times line-to-ground crest $E_{LN}$ or possibly even lower. As more data become available and industry standards are developed, improved switching-surge protective levels quite likely will be established. The tabulation does show, however, that present station arresters are well co-ordinated to switching surges for the reduced BIL's in current use and will provide protection to insulation even 10 per cent under the present reduced levels (column 3 in Table V).

**Table V. Protection Against Switching Surges with Lightning Arresters**

| Voltage Class, Kv | Arrester Rating, Kv | BIL | Switching-Surge Withstand, Kv* | Switching-Surge Protective Level, Kv* | Slow Switching-Surge Sparkover Voltage of Lightning Arresters |
|---|---|---|---|---|---|
| 242 (230) | 182 | 750 | 600 | 480 | 477 |
| 302 (287) | 228 | 900 | 720 | 575 | 604 |
| 362 (345) | 264 | 1,050 | 840 | 670 | 700 |

*Margin between protective level and withstand equals 25 per cent.

On the strength of Tables III and V, where the margin between protective level and withstand is 25 per cent, a lowering of the station insulation below the present reduced levels would not be realistic from the standpoint of switching-surge co-ordination. A 2-step reduction in BIL (column 3 of Table V) would require almost complete dependence on the arrester. Loss of the arrester simply would mean that the station insulation then becomes exposed not only to lightning surges, which are relatively infrequent in the large stations and in all probability sufficiently attenuated in effect by other measures of protection that normally complement the lightning arrester; but, in addition, in the absence of the arrester, the insulation also becomes vulnerable to switching overvoltages should these exceed about 2.4 times line-to-ground crest $E_{LN}$. It stands to reason that a reduction in station insulation below the present levels (column 2 of Table III) can come only through further advancements in the art and more extensive practical experience with the present reduced levels. As basic knowledge of the switching-surge problem becomes more firmly established and more reliance can be placed on the lightning arrester, then can protective margins be reduced with confidence and the application of a 2-step reduction in the insulation be accepted more generally.

Much development and standardization work remains to be done in regard to the capability of lightning arresters to discharge switching surges of the severity encountered in present-day power systems. Surge currents of 2,000-microsecond duration and approaching 1,000 amperes are cited by the arrester manufacturers in duty design tests applied to unit elements of the new arresters. All this is encouraging evidence that continued progress is being made in an effort to meet the requirements for present and future applications, but again one cannot overemphasize the continued need for field experience and studies to parallel the developments at the factory.

## NORMAL FREQUENCY OPERATION

THE THIRD BASIC REQUIREMENT in co-ordination is the ability of the insulation to withstand 60-cps voltages continuously, low-frequency system transients, or temporary overvoltages being considered part of this requirement. With each reduction in the insulation level, the normal frequency stresses in the insulation assume increasingly greater importance. Thus, for 230-kv grounded-neutral operation, a reduction in the BIL and corresponding low-frequency test from 1,050 to 825 results in an increase of nearly 30 per cent in the 60-cps stresses (column 5 of Table VI). Another 10 per cent rise in the 60-cps stresses would result in going from 825 to 750. Add to this the fact that in present competitive design the trend is toward reduced size and weight of the equipment, which in turn further tends to accentuate internal stresses rather than to reduce them.

**Table VI. Increase in Ratio between 60-Cps Operating Voltage and Low-Frequency Test with Reduced BIL's**

| Operating Voltage, Kv | Line-to-Ground Voltage, Kv | BIL Kv Crest | Low-Frequency Test, Kv Rms | Ratio of Column 2 to Column 4 |
|---|---|---|---|---|
| 230 | 133 | 1,050 | 460 | 0.29 |
| 230 | 133 | 900 | 395 | 0.34 |
| 230 | 133 | 825 | 360 | 0.37 |
| 230 | 133 | 750 | 325 | 0.41 |

Good life expectancy at 60-cps operating voltages therefore requires continual re-examination of the insulation problem to assure that over-all co-ordination is attained. For equipment in which the 60-cps stresses inherently are high, as in cables and potheads, it has been found good practice to introduce in the standards long-time acceptance tests (column 2 of Table VII), in order to assure more realistic co-ordination to life expectancy since the 1-minute or short-time low-frequency tests are of limited significance in this respect. The tests are supplemented with measurements of corona (ionization) determined by various methods: power factor, capacitance, oscilloscope method, and radio influence. This too, may well be the course for industry to follow, in the case of bushings and even other station equipment, should operating stresses in insulation continue upward and approach limits commensurate to the stresses in cables and in potheads and provided, too, that experience indicates the advisability of following such a course.

**Table VII. Long-Time Tests and Other Dielectric Tests Applied to Potheads***

| | Long-Time Test, Kv Rms | Low-Frequency Tests, Kv Rms | | Impulse Test |
|---|---|---|---|---|
| | | 1-Minute | 10-Second | 1.5×40 |
| Voltage, Kv | 6-Hour | Dry | Wet | Microsecond Crest, Kv, Full Wave |
| 69 | 118 | 175 | 145 | 350 |
| 92 | 139 | 225 | 190 | 450 |
| 115 | 163 | 280 | 230 | 550 |
| 138 | 191 | 335 | 275 | 650 |
| 161 | 221 | 385 | 315 | 750 |
| 196 | 268 | 465 | 385 | 900 |
| 230 | 315 | 545 | 445 | 1,050 |

*AIEE Standards for Potheads No. 48 (1948).

The combined problem of insulation co-ordination for the four conditions of service, including impulse, switching, 60-cps overvoltages, and normal 60-cps voltage, are shown in Fig. 1. The example refers to 230-kv 825-BIL transformer insulation. The lower curve represents maximum voltages to ground appearing at the station and the upper curve corresponding withstand levels for the transformer insulation.

Lowering the insulation two steps (from 1,050 to 750 BIL) results in a relatively greater reduction of margins in the two areas: switching surges and normal voltage continuous stress, as is clearly shown in Fig. 2. The impulse problem, once the most critical, now is the least critical because of the improved impulse protective characteristics of present-day station arresters. Similarly, adequate margins remain between the factory low-frequency tests and the 60-cps overvoltages in service.

## CONCLUSIONS

1. The present reduced insulation levels now applied in power systems operating with the neutral solidly grounded are generally well co-ordinated to the impulse, switching-surge, and 60-cps requirements.

2. A lowering in general of the insulation (BIL's) below these levels is not realistic at present because of the limited practical operating experience at these levels, and the essential need for more basic knowledge on the performance and co-ordination of station insulation to switching surges and to continuously applied 60-cps voltages.

3. A further rationalization of station insulation to switching surges and system transient overvoltages stands now as a major undertaking that requires the attention of the industry.

4. Another basic consideration that requires attention especially at the higher operating stresses is the performance and endurance of insulation to continuous 60-cps operation.

5. These fundamental factors once resolved should be conducive to a more effective utilization of station insulation, to better equipment performance and system reliability, and to lower BIL's.

6. These factors do not preclude the feasibility of a 2-step reduction in insulation at this stage. Such applications however, must be engineered individually and closely, each on its merit.

7. Even where a 2-step reduction in the insulation to ground is indicated, it is inadvisable to reduce the bushing and line-to-line insulation at this time more than one or one and one half step.

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# The Technical Feasibility of Translating Languages by Machine

V. H. YNGVE

**Language translations now can be implemented by general-purpose digital computers or, more economically, by using special-purpose machines. Either word-by-word or more accurate sentence-by-sentence translations are considerably faster and cheaper than man-made ones.**

RECENT developments in the design of electronic digital computers have suggested the possibility of translating languages by machine. However, when one tries to write a good translation program for a computer, one finds that there is much to be learned about language. For this reason, no program has yet been written by which a computer could translate usefully, but a number of people have been challenged by the problem of filling in the gaps in our knowledge about language and translation.[1,2]

This increasing interest in the possibility of mechanical translation is not surprising. Translation on a large scale is becoming more and more urgent in a rapidly shrinking world, still partitioned by many language barriers. There are at least 50 languages that possess written records worth translating; at least, 200 languages into which the scientific, technical, and cultural records of our civilization might be translated. The price that each language community pays for the luxury of expressing itself in its own language is the cost and the difficulty of communication with the rest of the world. Today, communication between language communities must be funneled through individuals who are to some extent bilingual. If special-purpose machines can be devised for translating written material, the cost of translation can be significantly reduced. Language communities could then retain their individuality and still gain the advantages of increased communication.

This article will explore two types of mechanical translation. The first, which can be called word-for-word translation, is within our immediate reach, but promises results that are crude, at best. The second type, sentence-for-sentence translation, which is the type being studied at the Research Laboratory of Electronics, Massachusetts Institute of Technology (MIT), Cambridge, Mass., promises translation of a higher quality, but will require a great deal of effort to work out the linguistic details.

## WORD-FOR-WORD TRANSLATION

WORD-FOR-WORD TRANSLATION is based on the use of a dictionary. The words of the input text are looked up in order, one by one, in a dictionary, and the meanings are written down in order, one by one. In determining the meanings, only one text word at a time is considered.

Word-for-word translations can be produced by machine in the following way: The material to be translated is typed on a keyboard device, which transfers the characters to some input medium such as punched tape, punched cards, or magnetic tape for entry into the machine. The machine then compares the words, one at a time, with the dictionary entries that are stored in the memory. When each input word is located in the memory, the dictionary entry stored there provides a meaning that consists of an equivalent word or words in the other language. The equivalents found in the dictionary are then sent one at a time to an output printer that prints a word-for-word translation.

If a machine that can produce rough translations on a production basis is wanted as soon as possible, the word-for-word machine is the favored type because it is simple and can be implemented now. If translations better than word-for-word translations are wanted, work on an automatic dictionary should still be undertaken. Any machine that translates will need a dictionary, and the technical problems arising in the design of an automatic dictionary are not trivial.

There are good reasons for taking the word, delimited by spaces or punctuation, as the item to be looked up, instead of some smaller unit. It has been suggested that if the roots of words and their inflectional endings were stored in the memory separately, much space would be saved in the dictionary. If a given word can be inflected in five ways, the number of entries in the dictionary could, perhaps, be reduced by nearly four fifths, since the inflectional endings are common to many words. As another space-saving device, it has been suggested that compound words, such as blackboard, counterelectromotive, and Koordinatenanfangspunkt, could be separated into their component parts, and each part looked up separately. Suggestions such as these for splitting up words have at least two disadvantages. One is that the separation of a word into parts before it is looked up requires a method for deciding where to make the separation. Part of the storage space saved has to be used for a more complicated program or look-up routine. Another disadvantage is that parts of words and inflectional endings have, in general, more different meanings than fully inflected words. Strict word-for-word translation completely avoids the segmentation problems and avoids some

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of the multiple meanings of parts of words—inflectional endings, in particular.

In the next sections, word-for-word translation will be considered, in detail. The requirements of the task will be compared with the capabilities of present-day general-purpose digital computers and of special-purpose machines that might be constructed for translation; then the usefulness of the product will be assessed.

## MACHINE REQUIREMENTS—SIZE

THE SIZE OF THE MEMORY of a machine is of importance in word-for-word translations. Memory size depends upon the number of dictionary entries, the average length of each entry, and, in stored-program machines, on the storage requirements of the program.

The number of words in a language is hard to estimate. If the entries in dictionaries are counted, numbers around a million are obtained. However, no dictionary contains all the words of a language; new words are being added every day. The vocabulary of a language is not a closed system; it is always open to additions. If translating is limited to one field of knowledge (electrical engineering, for example), most of the words belonging to other fields may never appear, and a glossary containing electrical engineering terms and certain general scientific terms might be adequate. But, like the vocabulary of an entire language, the vocabulary of a specific field is not closed; and an author of a paper in a special field often uses terms from other fields.

A glossary should contain the words most frequently used in a specific field. Since it is virtually impossible to list all the words of a language or even of a specific field, new words will have to be added from time to time as they are needed. It is feasible to start with a rather small list of words and add new ones whenever they are first encountered or after they have appeared a given number of times. In this way, the glossary is always an approximation to a list of the words of highest frequency in the specific field.

The most important parameter to be considered in evaluating a glossary is not the number of words that it contains, but some parameter connected with the number of running words of a text that can be found in the glossary. The coverage of a glossary with respect to a certain text can be defined as the ratio of the number of running words of the text that can be found in the glossary to one more than the number of words that cannot be found. It is the average length of uninterrupted runs of text words that can be found in the glossary. The coverage of an English glossary with respect to a Russian article is zero. The coverage of a glossary containing the 50 or 60 most frequently used English words is about one, because these words make up about half of the running words in a text. The coverage of a glossary with respect to an article is numerically equal to the number of words in the article, if the glossary contains them all. In order to have a reasonably high coverage with respect to a field, such as electrical engineering, a glossary should contain at least 5,000 carefully chosen words.

In assessing the size of memory needed for an automatic dictionary, it is also important to form some estimate of the length of each entry. The distribution of lengths of the different words in a language is characteristic of the language. In English, the average word length is about seven or eight letters; in German, it is somewhat longer. German has many words with more than 20 letters. Inasmuch as word lengths are so variable and because each entry may contain one or more words as equivalents, there will be considerable variation in entry size. Perhaps the average size will be something like 20 letters; the maximum size may run to more than 100.

The amount of storage needed for a minimum dictionary of 5,000 entries with an average entry size of 20 characters of 5 binary digits each is 500,000 binary digits.

Now that an estimate of the memory capacity requirements has been made, the adequacy of present-day machines can be examined. Many general-purpose digital computers have three kinds of memory: magnetic core, magnetic drum, and magnetic tape. A storage capacity of 500,000 binary digits is, by present standards, large for a magnetic-core memory. Even many magnetic-drum machines do not have this capacity. One is forced to the conclusion that magnetic-tape storage must be used with most present-day general-purpose computers if an adequate dictionary is to be stored.

## MACHINE REQUIREMENTS—SPEED AND ECONOMY

ALTHOUGH THE ABILITY of a machine to make word-for-word translations is determined primarily by the size of the glossary that it can store, its usefulness for producing translations economically depends on a number of factors. These include the cost of operating the machine, the access time of the memory, the register length, the type of commands available and their execution times, and the way in which the program is written.

In present-day machines the memories are organized by address. This means that the memory contains a number of pigeonholes or memory locations, each one designated by a number. The machine is arranged so that ready access is obtained to each memory location when it is referred to by its address. The average time that it takes to refer to a given address and extract the contents of the memory from that position is called the access time. For core memories the access times are very short, in the neighborhood of 10 to 20 microseconds. For drum and tape memories, the concept of access time is not quite as appropriate, because the actual time required to find something at a given address varies greatly, being dependent on the time it takes the drum or tape to move to that address. Average access times for drums are in the neighborhood of 10 milliseconds.

In a dictionary look-up program, the access time is not the whole story in determining how quickly a given word can be found; although the word is known, its address is not. The binary representation of the word itself cannot be used as the address, because the spelling of words is highly redundant. For a 5,000-word memory, the address would need to be only 13 binary digits long; but the spelling of a word might require well over 100 binary digits.

Various programming methods have been devised for searching a memory when the address is unknown. Clearly, it is not economical of time to start at the beginning and

examine each entry, in turn, through the whole dictionary until the right entry is found. An improvement consists of using the thumb index idea, whereby the search is divided into two steps. The initial one or two letters of the word are found in the index part of the dictionary. The index entry gives the position in the main list at which the search should begin. It is possible to extend the thumb-index idea and divide the search into three or more steps. If this procedure is carried to the extreme, the bifurcation, or 20-questions, technique is reached. Each step of the search chooses one out of two approximately equal sections of the dictionary. If the division is exactly into two, each time, one out of $2^n$ entries can be found in $n$ trials. Another possibility is to try to obtain from the spelling of the word some function that specifies, as closely as possible, the address of the word; surprisingly good results can be obtained.

It is also possible to take advantage of the vocabulary statistics. The probability $p_r$ that the $r$th word from the vocabulary will appear next in a text is given by the Zipf Law[3] as $p_r = Pr^{-1}$, where $r$ is the rank of the word when words are ranked in order of decreasing frequency, and $P$ is a constant with a value of approximately one tenth. A more accurate law has been derived by Mandelbrot.[4] It is $p_r = P\,(r+m)^{-B}$, where $B$ is a constant in the neighborhood of one, and $m$ is another constant. The constants $P$, $m$, and $B$ are characteristic of different languages and, to some extent, of different authors and styles of discourse. According to these two laws, as few as 50 or 60 different words make up about half of the total words in a text. If these 50 or 60 words are placed in a core memory with effectively instantaneous access, the over-all access time can be reduced by a factor of 2.

For a memory, such as magnetic tape, the access time to a given entry depends on its position along the tape in relation to the reading hands. The most effective way to use a magnetic-tape memory is to look up the words in batches, not one at a time. Each batch of words is alphabetized in the fast memory of the machine. All of the words in a batch can be looked up in one pass of the tape, if the words on the tape are also alphabetized. The average rate of access can be greatly increased by this method at the expense of some delay in translation and some storage and manipulation requirements in a fast memory. The concept of random access time is almost meaningless when words are looked up in batches. The appropriate parameters of the system are the average rate of information flow through the machine and the average delay.

Present-day digital computers have been designed to handle arithmetic at very fast rates. A dictionary search program for one of these machines usually involves a lot of arithmetic—not because it is required by the problem, but because the machine does it so well. A modern fast computer would not be as economical as a machine specifically designed for translation. Such a machine should be capable of handling entries of variable length and should be designed specifically for searching the memory, when the address is not known. It should be specially designed for matching sequences of binary digits, and determining whether the numerical value of one sequence is greater or less than that of another.

Memory research is progressing rapidly. In another few years, high-capacity magnetic-disk memories, special magnetic-tape or drum arrangements, or various types of photographic memories will probably be developed to the point where they will be available for translating machines. It may not be necessary to resort to word-splitting techniques in order to store a high-coverage glossary in a machine that is economical to use.

The simple word-for-word translation schemes that have been discussed have the advantage that they can be implemented now. In order to decide whether or not their implementation is worth while, the potential usefulness of the translations should be considered.

## USEFULNESS OF THE OUTPUT

If translation, from German to English, for example, is considered as the selection of one out of all possible sequences of English words for each German sentence, a word-for-word translation is a good first approximation. English sentences average about 20 words. Assuming a vocabulary of $10^5$ words, there are $10^{100}$ possible sequences of this length. A word-for-word translation may supply an average of about two meanings for each German word. If the word-for-word translation is good, the correct English translation can be found by choosing the correct meaning for each word from those supplied and, then, choosing the correct word order. The initial choice of one out of $10^{100}$ possible sequences has been reduced to one out of $2^{20} \times 20!$ or about one out of $10^{24}$. For each sequence left to choose from, approximately $10^{76}$ have been ruled out. It is thus seen that the word-for-word translation has done a Herculean job, but there is still a lot of work for the reader to do before he can read the translation. He must still choose one out of $10^{24}$ possibilities. This he presumably does on the basis of his knowledge of English sentence structure and on the basis of his knowledge of the subject matter. The problems of multiple meaning and of word order are the two difficulties that he must face.

To make the reader's task easier, various suggestions have been made for the arrangement of the multiple choices on the page. They could be strung out in linear order, perhaps with parentheses; or the most likely meaning for each word could be put first or written in bold type; or the various meanings could be listed in columns. Another question concerns the number of meanings that should be provided for each word. Perhaps one broad meaning would be less confusing than two or three narrower meanings. Another suggestion for making the reader's task easier is called partial translation. Partial translation is based on the fact that only a few hundred articles, prepositions, conjunctions, and adverbs make up a large majority of the running words in a text and that these words, together with a few inflectional endings, have especially long multiple-meaning lists. The suggestion is that these few hundred items be given in their original language in order not to confuse the reader with long lists. The reader, after a brief introduction to the grammar and sentence structure of the foreign language, would be able to understand these words and endings and the constructions in which they are used. All of the technical terminology would be translated.

The reader of the translation plays a vital role. In a sense it is he who makes the translation, because he alone understands the meaning. The machine only recodes the foreign language, so that it can be more easily translated by the reader. Experiments have shown that word-for-word translations can be deciphered more easily if the reader is familiar with the topic that is being discussed. If he knows what the author is trying to say, he can recreate the work with very few clues. Thus, word-for-word translation could be useful for people who want to keep abreast of large amounts of foreign technical literature in their field, but it would probably not be adequate for a careful reading of any one article.

It has been suggested that rough word-for-word translations should be revised and edited by an expert. For certain purposes revision may be advisable, but perhaps the best course would be to let the final reader make his own revision, since he is an expert in the field and can use his background knowledge in deciding what the author probably meant.

It is very important that the final reader be considered a link in the translation chain. Any improvement in the translation which speeds up the reader's comprehension is worth while, since the reader's time is expensive.

Thus, word-for-word translation can be implemented now by using present-day general-purpose digital computers or, more economically, by using special-purpose machines. The output might be useful, but would definitely be of poor quality, probably so poor that the reader would have to be highly motivated before he would want to use it.

## SENTENCE-FOR-SENTENCE TRANSLATION

ATTENTION now will be given to the question: How can a machine produce something better than a word-for-word translation? The deficiencies of word-for-word translations will be examined, not from the point of view of how a reader could cope with them, but rather of how a machine could cope with them. A diagnosis of the difficulties will be attempted, and a remedy will be proposed. This will necessitate some examination of the way in which words are combined to make sentences in a language.

## ANALYSIS OF DIFFICULTIES

THE MAJOR SHORTCOMINGS of word-for-word translations have been grouped under multiple-meaning difficulties and word-order difficulties. It is now advantageous to reclassify them as lexical difficulties and structural difficulties.

Lexical difficulties include the multiple-meanings of words like power, force, integrate, potential, and so on. It has been suggested that the use of a field glossary would restrict these words to one meaning, the technical one. A startling exception to the observation that most nouns, verbs, and adjectives have few meanings is the word *run*, which, according to Webster's Collegiate Dictionary, has 54. (The average number of meanings per word in Webster's Collegiate Dictionary is about 2.5.)

Structural difficulties include word order, inflectional endings, multiple meanings of most articles, prepositions, conjunctions, and adverbs. Most of the multiple-meaning difficulties in a text are structural because a majority of the running words in a text are structural words, with more than the average number of meanings. The 54 meanings of the word *run* are divided into four lists that are structurally different: transitive verb, intransitive verb, noun, and adjective. It is clear that a machine method of handling structural problems is highly desirable.

Diagnosis of the difficulties is easy—after all, a word is usually not ambiguous when its context is considered. In word-for-word translation, no attempt is made to translate a word in its context, but a meaning or meanings are assigned to it on the basis of its form alone. From this point of view, a word-for-word translation might be called a literal translation, whereas a translation which takes into account the context might be called a free translation. Whether a translation is literal or free really depends upon the point of view. A word-for-word translation translates words literally, but translates letters and syllables freely. Words may be translated freely if larger blocks are translated literally. In general, a literal translation will be better if it is based on larger blocks of text.

What is needed is a way to use the context in translating the words. Investigation has shown that using the context of a complete sentence is a great deal better than using smaller parts of a sentence, e.g., a phrase, but is not significantly worse than using the context of two or more sentences. A sentence seems to be a natural language unit. To see how the information in a sentence context can be used for translation, more knowledge of language structure is needed.

## STRUCTURE OF LANGUAGE

THE MOST SIGNIFICANT THING that can be said about a sentence is that it has a structure. Some hint of this is given in the grammar taught in grammar school, where words and groups of words are classified as nouns, verbs, subjects, objects, and so on, and simple sentences are parsed in order to illustrate the interrelation of their various parts.

It is rather illuminating to consider some of the quantitative aspects of sentence structure. Of the $10^{100}$ arbitrary sequences of 20 words, perhaps only $10^{30}$ to $10^{50}$ are actually English sentences. All of the rest, or practically all of them, are mere incoherent jumbles of words. Sentence structure thus places very strong constraints on the sequences of words. Another way of appreciating the degree of constraint imposed by sentence structure is to take an actual 20-word sentence from a newspaper and try to rearrange the words. Of the 20! different arrangements, only a few are English sentences. That there must be some structure or system underlying these constraints is apparent. A man in his lifetime would not be physically able to hear or speak more than $10^9$ sentences, yet he can instantly recognize whether any given sequence of 20 words is included among the $10^{30}$ to $10^{50}$ English sentences or is left in the remaining $10^{100}$ ungrammatical jumbles of words. He can do this by recognizing that the sequence conforms, or does not conform to one of the allowable sentence patterns. Recognition of sentence pattern is based primarily on formal features of the

sequence and not on the meaning; for the meaningless lines by Lewis Carroll

'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe:
All mimsy were the borogoves,
And the mome raths outgrabe.

are instantly recognized as conforming to English sentence patterns.

Constraints powerful enough to restrict the sequences of words to only those that conform to the sentence structures of a language can be represented by the following scheme. A set of structural choices is encoded into a sequence of words. The first step is to choose one of several possible sentence types. For English they might be

sentence = "I" + predicate *a*, or
sentence = "you" + predicate *b*, or
sentence = subject *c* + predicate *c*, or
sentence = "it" + predicate *p* + "that" clause. . .

In the foregoing, "sentence" stands for all sentences in English; "predicate *a*" stands for all predicates that can follow the first-person singular subject "I"; and so on. Take the example

sentence = "it" + predicate *p* + "that" clause

This means that the sentence will start with the word "it," followed by a particular type of predicate, predicate *p*, and followed in turn by a clause introduced by the word "that." The particular predicate of type *p* and the particular "that" clause will emerge as a result of further choices. For the predicate, the choices might be

predicate *p* = verb "to be" + adjective *b*, or
predicate *p* = verb "to be" + prepositional phrase, or
predicate *p* = verb "to be" + past participle *c*

The first of these might be chosen. Further choices would decide the tense of the verb—present tense, for example. For the adjective, the choices might be

adjective *b* = "clear," or
adjective *b* = "true," or
adjective *b* = "likely". . .

If "clear" is chosen, the sentence so far is: "It is clear + 'that' clause." Note that adjective *b* would not include adjectives like hot, red, small, and so on.

An encoding scheme of this sort can allow for certain types of recursiveness in sentence structure. For example

It is clear that it was likely that it was true that . . .

This type of recursiveness is indicated by

"that" clause = "that" + sentence

which leads back again to the beginning of the set of choices.

An encoding scheme of this sort, starting as it does with a set of choices or directions for producing a certain sentence and ending with the words of that sentence, can be thought of as a grammar of a language from the point of view of the speaker rather than of the listener. Schemes from the speaker's point of view have the advantage that each set of choices leads unambiguously to a unique sequence of words. On the other hand, a given sequence of words may be ambiguously represented by two or more different sets of choices. As an example of this, consider that

predicate *a* = "am here now," or
predicate *a* = "see it now" . . . and
predicate *b* = "are here now," or
predicate *b* = "see it now" . . .

Then "see it now" can be produced ambiguously as a first-person singular or a second-person predicate. A grammar from the listener's point of view could resolve this ambiguity only by consideration of the context "I" or "you." Similarly, words can have multiple meanings from a literal point of view, but be unambiguous if their role in the sentence structure is known. As an example, consider this English sentence

The (Der) man showed the (dem) boy the (das) picture.

and this part of a German sentence

Der (the) Mann, der (who) der (of the) Tat fähig ist, . . .

In this way, considerations of sentence structure can resolve many of the multiple-meaning problems.

Usually each possibility of choice of structure in a language has a meaning assigned to it. A distinction has been made between the "structural" meaning and the "lexical" meaning. The two sentences "The chair is on the rug." and "The rug is on the chair." have different meanings because the words appear at different positions in the structure. On the other hand, the difference in meaning between "The chair is on the rug." and "The chair is on the floor." is a lexical difference. Lexical meaning tells what sentences talk about; structural meaning tells what they say about it.

Just as different languages are different in their lexicography, they can also be different in their structure. Languages that are historically related are usually similar in structure. Even if two languages have certain structures in common, it may be that they assign different meanings to these structures. Languages may also differ in what aspects of the meaning are carried by structure and what aspects are carried by lexicography. The distinction between subject and object in a sentence is indicated structurally by word order in English, but in German it may be indicated by the lexical difference between the words "der" and "den." Similarly, the meaning that is assigned lexically to the word "if" in English is sometimes indicated structurally by word order in German.

## TRANSLATION OF STRUCTURE

IF TRANSLATION BY MACHINE is to be done on a sentence-by-sentence basis—using sentence structure to resolve the word order and the multiple meanings of the individual words, and correctly translating the structural meanings—grammars are needed for each language. These grammars should consist of descriptions of each language, which are complete enough to make the distinctions in meaning, that are necessary for translation—providing a description of this

sort for even one language is something that has not yet been done, because the concepts involved are just now becoming understood and because languages are extremely complex in their structures. Once two of these descriptions are available, they can be set side by side, and the equivalences stated. It must be decided which sentences in language *A* and language *B* are equivalent. The underlying assumption is that it is possible to find such correspondences. Of course, this assumption is not strictly true, for no two languages are completely translatable. The assumption is probably very nearly valid for related languages such as German, English, French, Russian, and for scientific discourse, or other types of careful exposition.

If a description of the structure of two languages and a statement of the equivalences in meaning between them are given, only one more thing is needed for a mechanized translation procedure: a mechanical method of recognizing the structure of a sentence from the sequence of words composing the sentence. The precise form of this recognition routine must await the description of the structures to be recognized. However, the process must operate from the point of view of the person who reads or hears a sentence. It must tentatively recognize small groups of words, place them in a tentative structure, and so proceed, each time eliminating certain possibilities. Once the structure of the sentence to be translated has been recognized, it can be translated into an equivalent structure in the other language, and the correct meanings can be chosen from the multiple meanings of the words.

## RESULTS TO BE EXPECTED

THE TRANSLATIONS produced by a routine that translates on a sentence-for-sentence basis will be vastly better than the output of a word-for-word translating machine. Most output sentences will be grammatically correct. There will be very few word-order problems remaining. Many of the multiple-meaning difficulties will be solved, particularly those involving the most frequent words of the language and the very frequent inflectional endings. There will be a partial solution to multiple-meaning problems such as the different meanings of the word "can," which are distinguished on the basis that one meaning is connected with a verb, one with an auxiliary verb, and one with a noun. There will be some multiple-meaning problems remaining. Of these, some can be resolved by judicious use of a field glossary or by related techniques. The rest must be resolved by the good sense and intelligence of the reader of the translation.

## CONCLUSION

The state of the art of mechanical translation can be summed up as follows:

1. Word-for-word translations can be made now on high-speed general-purpose digital computers.
2. Word-for-word translations could be made more economically by means of special-purpose machines built with existing technology.
3. Word-for-word translations promise to be considerably cheaper than man-made translations.
4. Word-for-word translations are very crude, but may be useful when more accurate translations are not worth the additional cost.
5. If something better than a word-for-word translation is desired, our best hope is to take into consideration the sentence structure in designing a translation routine.
6. Providing translation routines on a sentence-for-sentence or structural basis requires a considerable amount of detailed linguistic work.

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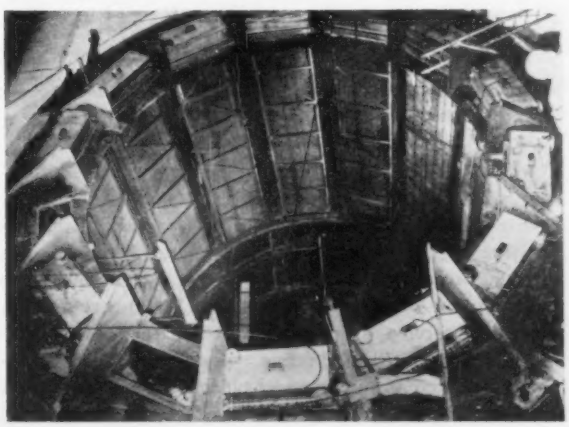
# Secondary Cooler for Supersonic Wind Tunnel

The secondary cooler shown at right during installation at the Lewis Flight Propulsion Laboratory at the Cleveland (Ohio) Airport is a component part of a new $33 million supersonic wind tunnel, designed for research on airplane engines of the future. The 10- × 10-foot tunnel will duplicate air speeds from two to three and one half times the speed of sound and will be able to handle engines and engine components up to 5 feet in diameter. Its 250,000-hp electric-motor drive is the most powerful of its kind.

To meet exacting conditions for the secondary cooler, engineers and officials selected *K*-Fin coils, manufactured by Griscom-Russell Company, Massillon, Ohio, a subsidiary of General Precision Equipment.

The over-all coil consists of 14 *K*-Fin bundles, each having 636 copper tubes. The total surface is 480,000 square feet.



# Heating and Mechanical Effects of Conductor Installation in Raceways

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**The American Iron and Steel Institute has sponsored an investigation of the current-carrying capacities of wires when installed in multiple in steel raceways with various percentages of raceway fill, in order to supplement the information available on this subject. The results are being presented to the National Electric Code Committee for study, with a view toward possible modification of the Code.**

THE NATIONAL ELECTRICAL CODE, which is prepared by a committee of the National Fire Protection Association, is the recognized American Standard for the safe installation of electric equipment in the United States. It is based on the combined experiences of all groups in the electrical industry and all factual information that is available at the time of each edition's preparation.

Sometimes the information available is not sufficiently complete to justify the inclusion of installation practices that might be considered safe if all the facts were known. One of the oldest of these is the current-carrying capacities of wires when installed in multiple in steel raceways with various percentages of raceway fill. In recognition of this condition, the American Iron and Steel Institute sponsored, as a public service, a fact-finding investigation of steel raceways when installed in different types of building construction with different numbers and types of wire. The results of the investigation will be made available to the National Electrical Code Committee with a view toward improvement of Code requirements.

**Table I. Heating Test, 2-Inch Conduit in Air**

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature,* C | Amperes | Volts | Temperature Range,† C | Calculated Derating Factor (Per Cent) |
|---|---|---|---|---|---|---|---|
| TW | 6 | 12 | 60 | 33 | 5.5 | 7.8 | 60 |
| RH-RW | 6 | 12 | 60 | 34.75 | 5.6 | 6.7 | 63 |
| RH-RW | 6 | 12 | 75 | 42.25 | 14.1 | 10 | 65 |
| RH-RW | 10 | 30 | 60 | 13.8 | 14.0 | 10 | 46 |
| RH-RW | 10 | 30 | 75 | 17.1 | | 12.2 | 57 |
| RH-RW | 10 | 20 | 60 | 15.1 | 10.2 | 10 | 50 |
| RH-RW | 10 | 20 | 75 | 18.9 | 13.5 | 12 | 63 |
| RH-RW | 10 | 12 | 60 | 19 | 7.6 | 7.2 | 63 |
| RH-RW | 10 | 12 | 75 | 24 | 9.7 | 10.5 | 80 |
| RH | 14 | 60 | 60 | 6.17 | 32 | 11.7 | 41 |
| RH | 14 | 60 | 75 | 7.55 | 40.75 | 18.9 | 50 |
| TW | 6 | 20 | 60 | 27.75 | 7.6 | 8.3 | 50 |
| RUH-RUW | 6 | 20 | 60 | 26.8 | 7.45 | 8.3 | 49 |
| RUH-RUW | 6 | 20 | 75 | 33.2 | 9.5 | 12.8 | 51 |

*Steady-state operating temperature of hottest conductor with listed current flow.
†Difference in temperature between hottest and coolest conductor.

One of the unique factors of the investigation was the co-operation of all segments of the electrical industry through the formation of an Advisory Working Committee which assisted in outlining a general test program. As the program progressed, the committee met with representatives of Underwriters' Laboratories, Inc., and discussed the work completed. Comments made during such discussions resulted in the extension and modification of the test program, represented by the four phases in this article. At the same time that the committee provided such practical guidance, it kept the interested divisions of the electrical industry informed of what was taking place, so that the investigation would be regarded in its proper light as a public service.

Wire, raceway, and cellular metal floor manufacturers provided the large amount of materials necessary for the investigation. A qualified electrical contractor, under the auspices of the National Electrical Contractors Association, worked with the Laboratories' engineers in the conduit pull-in test installations so that they would be comparable to typical installation practice throughout the United States.

## SCOPE

INASMUCH AS THE INSTALLATION REQUIREMENTS for more than nine wires in conduit or tubing and for the use of more than 20 per cent of the cross-sectional area of wireways and auxiliary gutters are not stated in the 1953 National Electrical Code, the scope of the investigation was divided into the following parts:

1. A study of the heating of more than nine rubber- or thermoplastic-insulated conductors in steel raceways as the result of carrying current under various load conditions.
2. A study of the mechanical factors affecting the installation of more than nine rubber- or thermoplastic-insulated conductors in the steel raceways.

## PURPOSE

THE INVESTIGATION was conducted in order to compile information, observations, and test data which could be used for analyzing the following:

Condensed text of paper 56-952, "The Heating and Mechanical Effects of Installing Insulated Conductors in Steel Raceways," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Fall General Meeting, Chicago, Ill., Oct. 1-5, 1956. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1956.

**M. M. Brandon** is with Underwriters' Laboratories, Inc., New York, N. Y.; **K. S. Geiges** and **L. M. Kline** are with Underwriters' Laboratories, Inc., Chicago, Ill.; **F. V. Paradise** was formerly with Underwriters' Laboratories, Inc., Chicago, Ill.

1. The applicable current-carrying capacity reduction factors for more than nine conductors.

2. The effect of load diversity in reference to the current-carrying capacity reduction factors and conductor operating temperatures.

3. The mechanical factors affecting the percentage of raceway fill of rubber- or thermoplastic-insulated conductors in steel raceways on the basis of the number and size of conductors with a maximum of four bends in a run up to 100 feet.

4. The relation of corresponding factors when applied to different types of steel raceways.

*Heating Test Setups.* In the heating tests on wires installed in rigid steel conduit or EMT (electrical metallic tubing) the wires were laid out in series and folded back on themselves a sufficient number of times to provide the number of wires to be tested. Thermocouples were inserted and the wires were pulled into the conduit. The assembly was placed in the test enclosure. The feeder conductors were connected to the current transformers through a fuse board, and the thermocouples were connected to the instrument to record the temperatures reached on the conductors. The heating source was adjusted to enable the thermostats to maintain the enclosure temperature at 30 ± 0.5 C. The current was adjusted to give the desired steady-state operating temperatures of 60 C or 75 C.

For conduit and EMT in thermal insulation, the test setup was modified by enclosing rigid conduit or EMT in fibered gypsum blocks (4 by 12 by 30 inches) for the heating tests of raceway in thermal insulation.

For steel wireway, the test setup was modified by placing the wires in several lengths of standard 2-by-2 steel wireway to form a continuous 30-foot length.

For flexible steel conduit, wires were pulled into a 30-foot length of 2-inch size.

For cellular metal flooring, the top surface of the floor was covered with a $2^1/_2$-inch layer of lightweight concrete. This insulating concrete was composed of 4 cubic feet of perlite concrete aggregate, one bag of portland cement, mixed with 9 gallons of water. The thermal conductivity ($k$ factor) of this mixture was 0.77. The wires, with thermocouples attached at the center of the 30-foot lengths, were pulled into the header duct. In one test, the wires were pulled into one of the 8-foot-long floor cells in the center of the floor. Access to the cell was made through a $2^1/_2$-inch conduit cell ell.

For underfloor raceway, a 30-foot length 1- by 3-inch

**Table II. Heating Tests, 2-Inch EMT**

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Temperature Range, C | Amperes | Volts | Temperature at EMT, C |
|---|---|---|---|---|---|---|---|
| **In Air** | | | | | | | |
| RH | 14 | 60 | 60 | 9.4 | 5.5 | 29.5 | 43.0 |
| RH | 14 | 60 | 75 | 16.1 | 6.8 | 36.5 | 49.0 |
| RH-RW | 10 | 30 | 60 | 11.1 | 12.35 | 12.5 | 43.6 |
| RH-RW | 10 | 30 | 75 | 15.6 | 15.9 | 17.2 | 51.5 |
| RH-RW | 6 | 12 | 60 | 5.6 | 32.2 | 5.25 | 45.4 |
| RH-RW | 6 | 12 | 75 | 7.2 | 39.75 | 6.75 | 50.5 |

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Temperature Range, C | Amperes | Volts | Temperature at EMT, C | Temperature at Side of Gypsum Block, C | Temperature at Top of Gypsum Block, C |
|---|---|---|---|---|---|---|---|---|---|
| **In Thermal Insulation** | | | | | | | | | |
| RH | 14 | 60 | 60 | 8.9 | 5.15 | 28.2 | | | 30.6 |
| RH-RW | 10 | 30 | 75 | 8.7 | 12.85 | 13.85 | 57.6 | 40.9 | 32.2 |
| RH-RW | 6 | 12 | 60 | 4.4 | 29.8 | 5.2 | 47.8 | 35.6 | 30.0 |
| RH-RW | 6 | 12 | 75 | 5.6 | 33.2 | 5.9 | 52.5 | 37.8 | 31.1 |

**Table III. Heating Tests, 2-Inch Conduit**

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Temperature Range, C | Amperes | Volts | Temperature at Conduit, C | Temperature at Top of Block, C | Temperature at Side of Block, C |
|---|---|---|---|---|---|---|---|---|---|
| **In Concrete** | | | | | | | | | |
| RH | 14 | 60 | 60 | 11.7 | 6.8 | 35.1 | 35.6 | 33.9 | 30.6 |
| RH | 14 | 60 | 75 | 13.6 | 8.3 | 44.0 | 39.9 | 37.2 | 32.2 |
| RH-RW | 10 | 30 | 60 | 9.3 | 15.8 | 16.8 | 37.2 | 35.6 | 31.1 |
| RH-RW | 10 | 30 | 75 | 11.5 | 20.0 | 21.6 | 42.0 | 39.4 | 32.8 |
| RH-RW | 6 | 12 | 60 | 5.3 | 40.5 | 7.2 | 37.2 | 35.6 | 32.2 |
| RH-RW | 6 | 12 | 75 | 7.3 | 49.5 | 8.8 | 40.4 | 37.8 | 33.3 |
| TW | 6 | 20 | 60 | 6.2 | 38.0 | 8.5 | 38.8 | 37.2 | 32.2 |
| TW | 6 | 20 | 75 | 10.2 | 46.5 | 10.5 | 42.0 | 39.4 | 32.8 |
| **In Thermal Insulation** | | | | | | | | | |
| RH | 14 | 60 | 60 | 9.5 | 5.4 | 28.0 | 43.0 | 34.4 | 30.0 |
| RH | 14 | 60 | 75 | 13.4 | 6.7 | 35.7 | 51.0 | 36.7 | 31.1 |
| RH-RW | 6 | 12 | 60 | 7.2 | 31.7 | 5.2 | 43.6 | 33.9 | 30.0 |
| RH-RW | 6 | 12 | 75 | 10.6 | 39.3 | 6.7 | 51.5 | 37.8 | 30.0 |

**Table IV. Heating Tests, $1^1/_2$-Inch Conduit in Air**

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Temperature Range, C | Amperes | Volts | Temperature at Conduit, C |
|---|---|---|---|---|---|---|---|
| RH-RW | 6 | 6 | 60 | 6.1 | 47.0 | 4.0 | 41.4 |
| RH-RW | 6 | 6 | 75 | 9.4 | 55.3 | 5.1 | 47.2 |
| RH-RW | 10 | 20 | 60 | 7.2 | 17.2 | 12.1 | 42.0 |
| RH-RW | 10 | 20 | 75 | 11.1 | 22.0 | 15.7 | 49.0 |
| RH | 14 | 36 | 60 | 6.7 | 7.7 | 19.2 | 40.9 |
| RH | 14 | 36 | 75 | 16.6 | 9.4 | 33.0 | 48.4 |

**Table V. Heating Tests, in Air**

| Wire Type | Wire Size, AWG | Number of Wires | Temperature, C | Amperes | Code |
|---|---|---|---|---|---|
| **2-Inch Conduit** | | | | | |
| RH-RW | 6 | 8 | 60 | 36.0 | 38.5 |
| RH-RW | 6 | 8 | 75 | 45.0 | 45.5 |
| **$1^1/_2$-Inch Conduit** | | | | | |
| RH-RW | 6 | 6 | 60 | 47.5 | 44.0 |
| RH-RW | 6 | 6 | 75 | 55.3 | 52.0 |

Table VI. Diversity Tests

| Wire Type | Wire Size, AWG | Number of Wires | Number Conducting | Operating Temperature, C | Amperes | Volts |
|---|---|---|---|---|---|---|
| **2-Inch Conduit in Air** | | | | | | |
| RH-RW | 6 | 12 | 4 | 60 | 59.5 | 3.5 |
| RH-RW | 6 | 12 | 4 | 75 | 70.0 | 4.2 |
| RH-RW | 6 | 12 | 8 | 60 | 41.3 | 4.5 |
| RH-RW | 6 | 12 | 8 | 75 | 49.5 | 5.8 |
| RH-RW | 10 | 30 | 10 | 60 | 23.0 | 8.0 |
| RH-RW | 10 | 30 | 10 | 75 | 27.8 | 10.1 |
| RH-RW | 10 | 30 | 20 | 75 | 20.5 | 14.6 |
| RH | 14 | 60 | 20 | 60 | 9.7 | 16.8 |
| RH | 14 | 60 | 20 | 75 | 11.8 | 21.2 |
| RH | 14 | 60 | 40 | 60 | 7.25 | 26.0 |
| RH | 14 | 60 | 40 | 75 | 8.95 | 32.0 |
| **2-Inch Conduit in Concrete** | | | | | | |
| RH-RW | 6 | 12 | 4 | 60 | 59.5 | 3.5 |
| RH-RW | 6 | 12 | 4 | 75 | 68.2 | 4.5 |
| RH-RW | 6 | 12 | 8 | 60 | 45.0 | 5.2 |
| RH-RW | 6 | 12 | 8 | 75 | 55.2 | 6.6 |
| TW | 6 | 20 | 8 | 60 | 42.3 | 5.0 |
| TW | 6 | 20 | 12 | 60 | 32.8 | 5.45 |
| RH-RW | 10 | 30 | 10 | 60 | 26.2 | 9.2 |
| RH-RW | 10 | 30 | 10 | 75 | 31.6 | 11.5 |
| RH-RW | 10 | 30 | 20 | 60 | 20.8 | 14.3 |
| RH-RW | 10 | 30 | 20 | 75 | 26.0 | 18.2 |
| RH | 14 | 60 | 20 | 60 | 10.6 | 18.5 |
| RH | 14 | 60 | 20 | 75 | 13.0 | 23.2 |
| RH | 14 | 60 | 40 | 60 | 8.5 | 29.3 |
| RH | 14 | 60 | 40 | 75 | 10.1 | 35.5 |

raceway was enclosed in a slab of concrete, and wires, with thermocouples attached at the center of the 30-foot length, were pulled into the wireway.

*Conduit Pull-In Test Setup.* Ten 10-foot lengths of 2-inch rigid steel conduit were assembled in the form of a square with four right-angle bends spaced at 20-foot intervals, with a pull opening at the end of each straight section. The assembly was rigidly staked on the floor of a building and the wires were pulled into the conduit by means of an electric winch. A spring-scale dynamometer was used to measure the force required for each pull.

To assure field conditions, the conduit installation was made by an electrical contractor. To assure an average interior surface, the pull-in test setup employed several manufacturers' conduits. The pulling in of the wires was done by the contractor's electricians while the data were recorded by laboratory personnel. Commercial lubricants were used as needed.

TEST RECORD—FIRST PHASE

*Heating Tests.* Heating tests were conducted with 12 No. 6 AWG, type RH-RW wires, representing 44-per-cent fill, installed in a 2-inch conduit in air. Initial currents for this and other heating tests were adjusted to conform with the following derating factors given by S. J. Rosch: for 10 to 15 conductors, 65 per cent; 16 to 24 conductors, 60 per cent; 25 to 30 conductors, 55 per cent; and 31 or more conductors, 50 per cent. The

Table VII. Heating Tests, Single-Phase and 3-Phase

| Specimen | Operating Temperature, C | Single-Phase Amperes | 3-Phase Wye Amperes |
|---|---|---|---|
| 2-In. Conduit in Air | 60 | 34.75 | 34.0 |
| 2-In. Conduit in Concrete | 60 | 40.5 | 39.6 |
| | 75 | 49.5 | 48.6 |

currents were then adjusted to give the steady-state operating temperatures desired, i.e., 60 C and 75 C.

This test was repeated with 30 No. 10 AWG, type RH-RW wires, representing 41-per-cent fill; with 20 and then with 12 wires of the same size and type.

Similar tests were made with 60 No. 14 AWG, type RH wires (41-per-cent fill) and with 12 No. 6 AWG, type TW wires. The type RH conductors were tested for 60-C and 75-C operation. The type TW conductors were tested only at their rated operating temperature of 60 C.

The results of these heating tests are given in Table I.

TEST RECORD—SECOND PHASE

*Heating Tests.* Heating tests were conducted with various types, sizes, and numbers of wires installed as follows:

2-inch conduit in air (Table I)
2-inch EMT in air (Table II)
2-inch EMT in gypsum blocks (Table II)
2-inch conduit in concrete (Table III)
2-inch conduit in gypsum blocks (Table III)
$1^1/_2$-inch conduit in air (Table IV)

To verify the currents specified in the National Electrical Code for 60 C and 75 C and for less than nine conductors, eight type RH-RW, No. 6 AWG wires were tested when installed in 2-inch rigid conduit in air. The test was repeated using six type RH-RW, No. 6 AWG wires, except $1^1/_2$-inch rigid conduit was used. The results are given in Table V.

Table VIII. Heating Tests, in Air

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Temperature Range, C | Amperes | Volts | Raceway Temperature by Thermocouple, C | Raceway Temperature by Thermometer, C |
|---|---|---|---|---|---|---|---|---|
| **2- By 2-Inch Wireway** | | | | | | | | |
| RH-RW | 1/0 | 8 | 60 | 7.2 | 100.5 | 3.5 | 38.8 | 38.0 |
| RH-RW | 1/0 | 8 | 75 | 10.5 | 132.0 | 4.5 | 43.0 | 42.0 |
| RH-RW | 6 | 20 | 60 | 9.5 | 32.0 | 8.4 | 38.0 | 38.0 |
| RH-RW | 6 | 20 | 75 | 13.5 | 39.5 | 11.2 | 42.0 | 42.0 |
| RH-RW | 10 | 54 | 60 | 12.8 | 12.1 | 22.0 | 37.8 | 37.0 |
| RH-RW | 10 | 54 | 75 | 24.4 | 15.1 | 28.1 | 41.4 | 40.0 |
| **2-Inch Flexible Steel Conduit** | | | | | | | | |
| RH-RW | 6 | 12 | 60 | 6.7 | 32.5 | 5.5 | 41.4 | 40.0 |
| RH-RW | 6 | 12 | 75 | 9.5 | 40.3 | 6.3 | 49.0 | 45.5 |
| RH-RW | 10 | 30 | 60 | 8.3 | 12.3 | 12.7 | 41.9 | 39.0 |
| RH-RW | 10 | 30 | 75 | 13.3 | 15.2 | 16.1 | 48.4 | 44.5 |
| RH | 14 | 60 | 60 | 8.4 | 6.3 | 27.1 | 42.5 | 42.0 |
| RH | 14 | 60 | 75 | 13.5 | 7.7 | 34.0 | 49.0 | 49.0 |
| **4-Inch Conduit** | | | | | | | | |
| RH-RW | 1/0 | 16 | 60 | 7.8 | 73.0 | 4.6 | 42.5 | 39.0 |
| RH-RW | 1/0 | 16 | 75 | 13.4 | 90.5 | 5.8 | 49.5 | 45.0 |
| RH-RW | 6 | 42 | 60 | 10.6 | 22.0 | 13.5 | 42.0 | 39.0 |
| RH-RW | 6 | 42 | 75 | 15.0 | 26.5 | 16.6 | 50.5 | 48.0 |

Table IX. Heating Tests, Cellular Metal Floor

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Temperature Range, C | Amperes | Volts | Raceway Temperature by Thermocouple, C |
|---|---|---|---|---|---|---|---|
| **"A" Header Duct** | | | | | | | |
| RH-RW | 6 | 20 | 60 | 8.6 | 40.0 | 10.0 | 30.0 |
| RH-RW | 6 | 20 | 75 | 13.4 | 48.6 | 12.7 | 33.9 |
| RH-RW | 10 | 54 | 60 | 16.6 | 15.5 | 23.0 | 26.7 |
| RH-RW | 10 | 54 | 75 | 24.5 | 19.5 | 29.4 | 32.2 |
| RH | 14 | 122 | 60 | 11.7 | 6.4 | 65.0 | 30.6 |
| RH | 14 | 122 | 75 | 11.2 | 7.2 | 80.0 | 35.0 |
| **"B" Header Duct** | | | | | | | |
| RH-RW | 6 | 26 | 60 | 7.8 | 34.8 | 13.0 | 42.5 |
| RH-RW | 6 | 26 | 75 | 11.1 | 40.8 | 15.5 | 49.0 |
| RH-RW | 10 | 68 | 60 | 10.0 | 13.1 | 30.3 | 35.0 |
| RH-RW | 10 | 68 | 75 | 14.5 | 16.0 | 37.5 | 40.0 |
| RH | 14 | 136 | 60 | 11.8 | 5.9 | 62.0 | 37.8 |
| RH | 14 | 136 | 75 | 19.5 | 7.1 | 84.0 | 43.6 |
| **"A" Floor Cell** | | | | | | | |
| RH-RW | 6 | 16 | 75 | 14.2 | 42.5 | 9.5 | 36.1 |
| **"B" Floor Cell** | | | | | | | |
| RH-RW | 6 | 16 | 60 | 10.0 | 36.0 | 8.1 | 31.6 |
| RH-RW | 6 | 16 | 75 | 13.4 | 41.5 | 9.5 | 35.0 |

Table X. Transient Heating Test, 2-Inch Conduit in Air

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Amperes, Start of Test | Amperes, End of Test |
|---|---|---|---|---|---|
| **1-Hour Test** | | | | | |
| RH-RW | 6 | 12 | 60 | 51.0 | 48.0 |
| RH-RW | 6 | 12 | 75 | 62.0 | 56.5 |
| RH-RW | 10 | 30 | 60 | 20.0 | 18.5 |
| RH | 14 | 60 | 60 | 9.0 | 8.3 |
| **2-Hour Test** | | | | | |
| RH-RW | 6 | 12 | 60 | 48.5 | 44.5 |
| RH-RW | 10 | 30 | 60 | 19.3 | 18.2 |
| RH | 14 | 60 | 60 | 8.6 | 7.9 |
| **3-Hour Test** | | | | | |
| RH-RW | 6 | 12 | 60 | 48.0 | 44.3 |
| RH-RW | 10 | 30 | 60 | 19.0 | 17.2 |
| RH | 14 | 60 | 60 | 8.2 | 7.5 |

*Load Diversity Tests.* To determine the effect of load diversity when only some of the conductors installed in rigid conduit in air were carrying current, several tests were conducted with various types, sizes, and numbers of wires.

The results are given in Table VI.

*Single- vs 3-Phase Heating.* To determine the effect on conductor heating by single- and 3-phase currents, 12 type RH-RW No. 6 AWG wires were installed in 2-inch rigid conduit in air and tested by using first single-phase current and then 3-phase current of a wye-connected supply.

The results are given in Table VII.

TEST RECORD—THIRD PHASE

*Heating Tests.* Heating tests were conducted with various types, sizes, and numbers of wires installed in 2- by 2-inch steel wireway, 2-inch flexible steel conduit, and 4-inch rigid steel conduit.

The results are given in Table VIII.

Heating tests were conducted with various types, sizes, and numbers of wires in two different types of cellular metal floors, first with the wires installed in the header duct and then in the floor cell.

The results are given in Table IX.

*Transient Heating Tests.* Transient heating tests were conducted on wires in 2-inch rigid steel conduit in concrete in order to determine the current load which would provide a 30-C and 45-C rise in temperature of the conductors within 1, 2, and 3 hours starting with an ambient temperature of 30 C. Twelve

Table XII. Pull-In Tests on a 100-Foot Length of 2-Inch Conduit with Four Right-Angle Bends

| | Average Pull in Pounds* 40 Per-Cent Fill | | | | |
|---|---|---|---|---|---|
| | 12 No. 6 AWG, Type RH-RW | 30 No. 10 AWG, Type RH-RW | 40 No. 14 AWG, Type RH-RW | 16 No. 6 AWG, Type TW | 60 No. 10 AWG, Type TW |
| 1st Pull | 15 | 30† | 40 | 20 | 30 | 125 |
| 2nd Pull | 45 | 60† | 60 | 100 | 50 | 500 |
| 3rd Pull | 100 | 100† | 125 | 110 | 125 | 750 |
| 4th Pull | 210 | 450† | 260 | 225 | 235 | 850 |
| 5th Pull | 300 | 750† | 425 | 300 | 290 | 2250 |

| | 50 Per-Cent Fill | | | |
|---|---|---|---|---|
| | 75 No. 10 AWG, Type TW | 124 No. 14 AWG, Type TW | 13 No. 6 AWG, Type RH-RW | 37 No. 10 AWG, Type RH-RW |
| 1st Pull | 225 | 125 | 50 | 70 |
| 2nd Pull | 525 | 400 | 70 | 340 |
| 3rd Pull | 900 | Test discontinued, broken wires | 100 | 540 |
| 4th Pull | 1550 | | 200 | 740 |
| 5th Pull | 3000 | | 275 | 965 |
| Remarks | Stretched 2 inches | | No stretch | Stretched 5 inches |

| | 50 Per-Cent Fill | | 60 Per-Cent Fill | 70 Per-Cent Fill |
|---|---|---|---|---|
| | 51 No. 14 AWG, Type RH-RW | 21 No. 6 AWG, Type TW | 16 No. 6 AWG, Type RH-RW | 19 No. 6 AWG, Type RH-RW |
| 1st Pull | 25 | 55 | 35 | 50 |
| 2nd Pull | 85 | 125 | 100 | 100 |
| 3rd Pull | 275 | 175 | 250 | 800 |
| 4th Pull | 250 | 350 | 500 | 1500 |
| 5th Pull | 550 | 425 | 1050 | Test discontinued, stretched 2 inches |
| Remarks | One-half stretched, 2 inches | No stretch | Stretched 2 inches | |

*Maximum forces ranged from 25 to 100 per cent more than average.

†Cold weather check test.

Table XI. Heating Tests

| Wire Type | Wire Size, AWG | Number of Wires | Operating Temperature, C | Temperature Range, C | Amperes | Volts | Wireway Temperature by Thermocouple, C | Wireway Temperature by Thermometer, C |
|---|---|---|---|---|---|---|---|---|
| **1- by 3-Inch Underfloor Raceway in Concrete** | | | | | | | | |
| RH-RW | 6 | 12 | 60 | 17 | 53 | 8.85 | 31 | 30 |
| RH-RW | 6 | 12 | 75 | 23 | 63.5 | 11.1 | 37 | 34 |
| RH-RW | 10 | 30 | 60 | 15 | 21 | 20 | 30 | 29.5 |
| RH-RW | 10 | 30 | 75 | 15.5 | 25.5 | 26 | 36 | 39 |
| **1/2-Inch Rigid Steel Conduit in Air** | | | | | | | | |
| RH-RW | 10 | 2 | 60 | | 44 | 3.2 | 45 | |
| RH-RW | 10 | 2 | 75 | | 53 | 3.5 | 52 | |
| RH-RW | 14 | 4 | 60 | 5.5 | 18.8 | 7.0 | 48 | |
| RH-RW | 14 | 4 | 75 | 3 | 27 | 9 | 50 | |
| **2-Inch Rigid Steel Conduit in Air** | | | | | | | | |
| RH-RW | 6 | 16 | 60 | 7 | 40 | 8.25 | 44 | |
| RH-RW | 6 | 16 | 75 | 10 | 47 | 10.4 | 53 | |

**Table XIII. Examination and Dielectric Test Following Pull-In Test**

| Number of Wires | Wire Size, AWG | Wire Type | Per-Cent Fill | Remarks |
|---|---|---|---|---|
| As excessive damage or no damage whatsoever was noted on the following, only examination was necessary: | | | | |
| 30 | 10 | TW | 40 | The copper was exposed from 2 to 4 inches in at least one conductor every 5 feet by a tangential-type cut in the insulation. |
| 75 | 10 | TW | 50 | Similar to 40 per cent fill except copper exposed at 4-foot intervals with clusters of wires damaged at some locations. |
| 124 | 14 | TW | 50 | At least two conductors completely severed. Clusters of six to eight wires damaged at some locations. |
| 12 | 6 | RH-RW | 50 | No marks or scuffs. |
| 13 | 6 | RH-RW | 50 | No marks or scuffs. |
| A one-minute, 1,500-volt, a-c dielectric test was conducted on the following: | | | | |
| 40 | 14 | RH-RW | 40 | OK except one wire. Examination disclosed two jagged edge cuts approximately 1/4 inch long in the direction of the binder thread. |
| 12 | 6 | RH-RW | 40 | Withstood test potential. |
| 16 | 6 | TW | 40 | OK except one wire. Copper exposed for approximately 3 1/2 inch by tangential slice cut in insulation. |
| 21 | 6 | TW | 50 | OK except one wire. Examination disclosed jagged scuffed insulation damage. Breakdown occurred at 1,000 volts. |
| 37 | 10 | RH-RW | 50 | Withstood test potential. No visual damage. |
| 51 | 14 | RH-RW | 50 | Withstood test potential. No visual damage. |
| 19 | 6 | RH-RW | 70 | Withstood test potential, although braids were scuffed at some locations. |
| 16 | 6 | RH-RW | 60 | Slight scuffs on braid. Withstood test potential. |

type RH-RW, No. 6 AWG wires were used in this test. The test was repeated with 30 type RH-RW, No. 10 AWG wires and then with 60 type RH, No. 14 AWG wires.

The results are given in Table X.

*Load Diversity Tests.* Load diversity tests were made with various types, sizes, and numbers of wires installed in rigid conduit in concrete with only some of the conductors carrying current.

The results are given in Table VI under the heading "2-inch Conduit in Concrete."

### TEST RECORD—FOURTH PHASE

*Heating Tests.* Twelve type RH-RW, No. 6 AWG wires were installed in 1- by 3-inch steel underfloor raceway. The test was repeated with 30 type RH-RW, No. 10 AWG wires.

For comparison, two type RH-RW, No. 10 AWG wires were tested in 1/2-inch rigid steel conduit in air. The test was repeated with four type RH-RW wires.

To determine the effect of heating of wires occupying more than 40 per cent of the internal cross-sectional area of the raceway, 16 type RH-RW, No. 6 AWG conductors were tested in 2-inch rigid steel conduit in air. Sixteen No. 6 AWG wires comprise 60-per-cent raceway fill.

The results of these tests are given in Table XI.

*Conduit Pull-In Tests.* To determine the physical limitations of the placement of wires in a raceway, pull-in tests were conducted with 40, 50, 60, and 70 per-cent fill using various combinations of types, sizes, and numbers of wires.

The wires were pulled into the conduit at a rate of approximately 1 foot per minute. The force necessary for each incremental 20-foot pull was recorded yielding measurements for the following: 20 feet, straight; 40 feet, one 90-degree bend; 60 feet, two 90-degree bends; 80 feet, three 90-degree bends; 100 feet, four 90-degree bends.

The results are given in Table XII.

Following the pull-in tests the wires were pulled out of the conduit and examined. Some of the wires were immersed in a tank of water and subjected to a dielectric strength test at 1,500 volts held for one minute, removed from the water, and examined for damage.

The results of the examination and test are given in Table XIII.

### RECOMMENDATIONS

THIS ARTICLE does not specify, for the design engineer and others, a specific set of current reduction factors for use with more than nine conductors in a steel raceway nor an increased raceway fill percentage for wireways and auxiliary gutters where a current reduction factor is applied. An analysis of the factual data indicates that the following additions to the National Electrical Code as proposed by the Advisory Working Committee, are appropriate:

1. That the reduction factors, applicable to Table I of the National Electrical Code, for more than nine insulated conductors in a steel raceway give recognition to load diversity and be 70 per cent for 10 to 24 conductors, 60 per cent for 25 to 42 conductors, and 50 per cent for 43 and more conductors.
2. That 40 per-cent raceway fill be used for all raceways, including wireways and auxiliary gutters.

## Classified Area Guarded by TV

A Philco Corporation industrial television (ITV) installation is being used in security control at the company's Government and Industrial Division at Philadelphia, Pa. By using ITV, one plant guard can now observe three entrances to classified areas. The inner door of each classified area is secured by electric locks which are controlled from the guard post. In addition to performing a utilitarian task, the ITV installation is expected to furnish valuable information on the potential use of such systems in other types of plant control. The man shown on the television monitor awaits identification by the guard.

# Transmission of Business Machine Data

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FELLOW AIEE

THE TRANSMISSION of digital information in connection with the operation of business machines is engaging increasing attention of communication engineers. High-speed electronic computer-type machines are being called upon more and more to operate on information fed from distant points. This new form of record communication results in encoded information which is not at all intelligible in the accustomed sense. It is, nevertheless, telegraphy in every sense of the word.

Although it may be expedient to carry out computer functions of the business machine at high speed, the operating speed of the communication circuits which bring information from distant business offices may be quite different.

Presently, extensive use is being made of conventional telegraph facilities and equipment in the field of data processing. Fortunately, however, modern record communication facilities lend themselves readily to most present needs for data transmission. A substantial number of telegraph channels, for the most part operating at 65 words per minute speed (45 bits per second), already serve the automation of business in integrated data-processing systems. A few such systems involve interconnections operating at 56 bps (bits per second) and others are planned for 75 bps.

The modern telegraph plant was designed in contemplation of widespread use of 100-word-per-minute telegraphy. Excellent transmission efficiency and long-term stability at this higher rate are secured through the universal use of frequency modulation, which provides considerable freedom from interruptions due to changes in the "vehicle" channel as well as from errors due to extraneous disturbance from all sources.

In simplest language, these advantages accrue from the circumstance that positive control is maintained at all times. In transmission, a YES bit is represented by a certain frequency, and a NO bit by another frequency. This contrasts strongly with amplitude modulation, where YES is represented by the presence of a carrier, and NO is only presumed because nothing is transmitted during the intervals of all NO bits. In the AM, on-off method, spurious impulses due to either man-made or natural interference may be easily interpreted as YES during a "nothing" period. The second great advantage of FM also follows from the fact that YES and NO are represented by equal-valued signals of different frequencies. Changes in signal strength do not cause shortening or lengthening of the YES bit with respect to the NO. Design objectives and automatic controls notwithstanding, attenuation changes on the vehicle carrier system do occur. Balancing, shielding, and other precautions mitigate but never completely eliminate noise, particularly the "abnormal" peaks.

The absolute propagation time of a telegraph circuit is ordinarily not a significant characteristic. In the design of a data-transmission system, however, absolute delay may be of considerable consequence, particularly if an answer-back or an automatic error-correction function is involved. The absolute delay from sending mechanism to receiving mechanism is about 30 milliseconds. This parameter of the usual telegraph transmission facility perhaps should be somewhat more carefully broken down. In the first place, there are differences in absolute delay between channels, amounting to nearly 5 milliseconds. These differences in delay between paralleling circuits may also be of consequence in the design of terminating equipment for data-handling systems. Whenever the necessity appears such discrepancies may be easily equalized by means of a delay insertion network. Between any two trunk telegraph channel terminal points the delays may readily be made equal within 200 microseconds.

In addition to the delay of about 30 milliseconds due to channelizing equipment, there are delays due to vehicle band equipment and to line propagation. The vehicle band equipment may be approximated at 1 millisecond per band section (two terminals). The line propagation time on wide-band systems, including repeaters, is approximately 8 microseconds per mile. Microwave facilities, exclusive of channelizing equipment but which include repeaters, account for about 6 microseconds delay per mile.

Whenever there are telegraph sections connected together in tandem, distortion is greater than for the single section. Generalizations on the amount of distortion on multisection circuits are of little value. Whenever, after 3 or 4 tandem section interconnections, it exceeds 25 per cent, regenerative repeaters are employed. These restore transmission efficiency to about 100 per cent and the signals then may be passed through a number of additional sections before becoming materially degraded again.

Present-day trunk telegraph facilities were designed to have adequate margin and dependability to permit the elimination of the editing necessarily accompanying the older methods. Message traffic today is largely automatically routed. In any event, no more than the address is subject to human scrutiny anywhere between origin and destination. Transmission efficiency must of necessity be excellent or an intolerable number of messages would arrive at wrong destinations. In addition, modern private-wire telegraph networks often call for many telegraph sections to be connected together in tandem. This requirement, too, demands facilities of excellent performance. For these reasons, the telegraph plant is being found highly satisfactory for integrated data processing.

Digest of paper 56-654 "Transmission of Business Machine Data over Standard Telegraph Channels," recommended by the AIEE Committee on Telegraph Systems and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, San Francisco, Calif., June 25–29, 1956 Scheduled for publication in AIEE *Communication and Electronics*, 1956.

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# A High-Voltage Insulation Tester and Its Application to Railway Electrical Equipment

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**A new d-c test instrument, which makes it possible to extend d-c testing to traction electrical equipment, is described and procedures for applying this test to wound equipment are detailed. Results, as derived from a number of representative tests using the set, are given.**

DURING THE ERA of steam locomotives, failure of auxiliary electric equipment in railroad operations has been a relatively minor problem. With the introduction of trolley-fed electric locomotives and the more recent shifting from steam locomotives to diesel-electric locomotives, an effective electrical maintenance program has become an important part of efficient railroad operations. Because this is still a comparatively new field in the long history of railroad operations, railroad electrical maintenance techniques are still in a relatively "fluid" stage as compared with, for instance, the electrical maintenance program of the electric power companies.

There are many railroad operating functions in which the continuous and dependable operation of electric equipment is a prime requirement. For example, on electrified systems, if electric power failed, the entire operations would cease until a substitute form of motive power was made available or until repairs were made and power restored. On dieselized systems, failure of the electric equipment on diesel-electric locomotives can seriously disrupt normal operations, although on both types of systems, failure of the signal systems can be a very serious matter. That this is a matter of grave and increasing importance to the railroads is clearly indicated by the serious effect on train schedules when locomotive breakdowns occur.

A further factor involved in railroad electrical maintenance problems is the severe operating conditions to which electric equipment is subjected. Dirt, heat, moisture, and vibration are some of the major enemies of electrical insulation. In the design of electric machinery, much effort is directed toward elimination of these enemies of insulation. However, complete elimination is not possible, especially in mobile electric machinery. Vibration, moisture, dirt, and heat are always present in varying amounts and, consequently, the electrical insulation on mobile electric machinery, equipment, and wiring suffers accordingly.

One of the more difficult problems in railroad electrical maintenance work is to know that the insulation is in good condition and that such insulation is not going to fail without warning. Insulation breakdown is a prime cause for electrical failures and resultant delays in train movements, particularly on main-line locomotives.

Fig. 1. D-c test set, 0–5-kv output, 110-volts 40-watts input, equipped with sensitive vacuum-tube microammeter to detect currents from 0.002 microampere to 1 milliampere in five ranges.

## INSULATION FAILURE

THE MAJOR PROBLEM for discussion in this article is how to detect deterioration in the electrical insulation of the various parts of mobile electric machinery before actual breakdown and failure in service occurs and by a test method which, in itself, does not damage the insulation.

In railroad operations, there are many different pieces of electric equipment that must continue to function without failure in order to maintain schedules at full efficiency. In diesel-electric equipment, the electric transmission consists of the main generator, traction motors, and associated control and auxiliary equipment. Failure of any of these items would cause the locomotive to become inoperative. The auxiliary equipment includes the generator exciter, auxiliary generator for low-voltage circuits and battery charging, variable-speed traction motor blowers, auxiliary generator to power the traction motor blowers and radiator cooling fans, dynamic braking equipment including resistors and blowers, and other miscellaneous small pumps and blowers. Failure of any of these auxiliary items would cause either complete shut down of the entire unit or greatly reduced efficiency. Because of weight and space limitations, the

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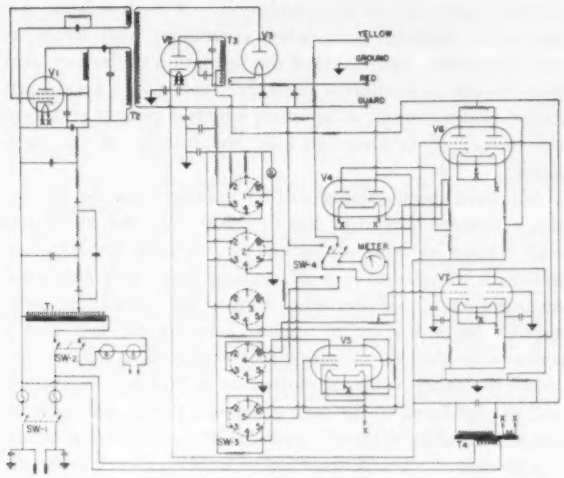


Fig. 2. Schematic circuit diagram of d-c insulation tester.

insulation of equipment, especially the traction motors, is thinner, stressed more, and worked harder under more adverse conditions than on almost any other class of equipment. Before applying insulation tests to traction motors and generators of the types and sizes used on diesel-electric and a-c trolley locomotives and cars, one must take into consideration the different designs and operating conditions. Although there has been extensive application of d-c testing to high-voltage stator windings, as used in the main generators of electric power systems, and many papers have been published giving the results of these tests, comparatively little d-c testing has been done on railway equipment.[1]

To provide maximum ratings in the available space, the armature windings of traction propulsion motors take advantage of the dielectric and heat resistant properties of the more recently developed insulation materials and are provided with a lower thickness insulation wall when compared with similar traction equipment of older designs. In general, these units are provided with Class H or Class B, or a combination of the two classes of insulation.

A number of authors in earlier technical papers have pointed out the advantages of maintaining records of the insulation resistance as periodic d-c tests may be applied to a winding during normal overhaul or maintenance outages.[2] It is now the practice of most operators of transportation motors and generators to schedule regular overhaul equipment outages, either on a mileage basis or on a calendar basis. Therefore, tests which would indicate the relative condition of insulation will fit very nicely into these regularly scheduled maintenance service periods. An instrument, described in the following section, has been developed which will permit the accumulation of the test data necessary for fulfilling the requirements suggested in this discussion.

## DESCRIPTION OF TEST SET

THIS INSTRUMENT incorporates the requirements for a field insulation test set, including performance, sensitivity, portability, ruggedness, freedom from damage to the equipment under test, and safety for test personnel.

The 5-kv insulation test set, shown in Fig. 1, is a suitable instrument for performing insulation resistance and d-c over-potential tests on medium-sized electric systems in the 1,000 volt and lower voltage classes, such as railway mobile diesel-electric equipment. Its continuously variable power supply and unusually sensitive microammeter permit the making of accurate insulation resistance tests on anything from the smallest test sample to the largest traction motor or generator. Its full 5,000-volt output voltage allows over-potential tests to be made on all low- and medium-voltage classes of equipment. For the schematic diagram of this instrument, see Fig. 2.

The high-sensitivity wide-range microammeter of this instrument indicates insulation leakage currents from 0.01 microampere to 1.0 milliampere. This very wide range of current (contained in five meter ranges of 0.1, 1.0, 10, 100, and 1,000 microamperes full scale) includes values of leakage current likely to be encountered in almost any test situation. The 5,000-volt power supply has rated current output of 1.0 milliampere. In actual practice, somewhat more current than this is available for short periods without danger of damage to the instrument. The instrument is not harmed if its output is short-circuited for a short period.

Two high-voltage terminals are provided: a yellow terminal which is connected through a high value current limiting resistor, and a red terminal which is connected directly to the power-supply output. The maximum current to the yellow terminal is limited to a value such as to create no hazard of dangerous shock if the operator should accidentally come in contact with wires connected to this terminal. Although the steady short-circuit current through the red terminal is very small, the surge caused by the discharge of the internal capacitors on shorting is appreciable, and standard safety practices for handling high-voltage equipment should be followed when using this terminal.

A guard terminal also is provided for making guarded insulation resistance tests, when desired.

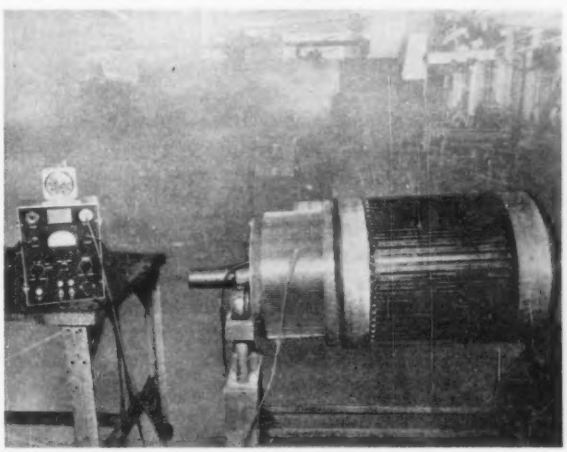

Fig. 3. Typical arrangement for making insulation tests using 5-kv d-c tester on a traction-motor armature.

This test instrument is small in size (less than 1-foot cube) and light in weight (less than 15 pounds). It is housed in a sturdy light-weight aluminum cabinet. A standard convenience outlet (115 volts, 60 cps) is required to power the instrument. Power consumption of the instrument is less than 40 watts.

## D-C INSULATION TEST PROCEDURES

THE FEATURES SOUGHT in a test procedure intended especially for use in a railroad electrical insulation maintenance program include: (1) reasonable certainty of the present condition of the insulation, i.e., whether the insulation under test is in sound condition and may be operated under full load for a further period without additional testing; (2) complete portability of the test equipment, i.e., small and light enough to be carried easily by one man; (3) rugged test equipment that is not easily damaged or put out of adjustment by normal usage; and (4) safe test equipment, i.e., safe from the standpoint of the operator and also safe from the standpoint that the test will not damage or weaken the insulation test specimen.

This last requirement is of particular importance to the electrical maintenance men on railroads as, under the Inter-

DC TEST DATA

DATE: 11-15-55
MAKE:
TYPE: TRACTION MOTOR ARMATURE
TEMPERATURE: 72°F
REMARKS: NEW WINDING - NEW COMMUTATOR

| KILO-VOLTS | TIME IN MINUTES | | | | | |
|---|---|---|---|---|---|---|
| | 1/2 | 1 | 2 | 5 | 10 | |
| .50 | .48 | .37 | .26 | .16 | .09 | |
| 1.0 | .62 | .44 | .34 | .21 | .16 | |
| 2.0 | 1.5 | 1.0 | .72 | .46 | .37 | |
| 3.0 | 1.9 | 1.4 | 1.1 | .70 | .57 | |
| 4.2 | 2.2 | 1.8 | 1.4 | 1.1 | .74 | |

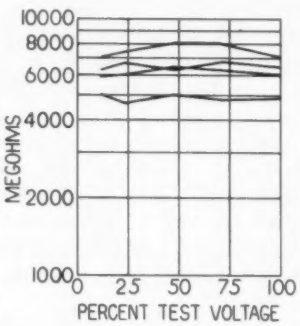


**Fig. 4 (*left*). Form used for recording test data. The recorded values in microamperes show the relatively small leakage currents involved in these tests. Fig. 5 (*right*). Installation resistance vs voltage curves for new traction-motor armatures.**

state Commerce Commission's (ICC) Rule *253*, an overvoltage test on all locomotive electric equipment is required at least once a year. This ICC rule reads as follows: "Not less than once every year, an insulation dielectric test of not less than 1-minute duration shall be applied to all circuits and parts carrying current with potential of more than 150 volts. The voltage applied to circuits, other than motor or generator windings, shall be not less than 75 per cent above the normal working voltage; the voltage supplied to windings shall be not less than 50 per cent above the normal working voltage. A careful examination shall be made of any weakness indicated and all defects remedied before the locomotive is put in use."

An a-c high-potential test may be applied to meet ICC requirements, but does not provide any indication of the relative condition of the insulation. A high-voltage d-c insulation resistance test, when correlated with temperature, humidity, cleanliness of the insulation under test, and past records of insulation resistance, can give a good indication of the amount of moisture which is present either on the surface of, or absorbed into, the interior of the insulation.

Standard specifications[3] call for making these d-c insulation resistance tests from 500 to 5,000 volts for all classes and voltage ratings of machinery. Recent investigation indicates the desirability of making insulation resistance measurements considerably above the operating voltages.[4,5] Some research[4,6,7] points towards the fact that a series of insulation resistance measurements, made at successively higher voltages plotted as a function of voltage and extrapolated to the zero resistance point, will indicate the approximate dielectric strength of the insulation before it is actually broken down. Other workers claim, however, that this is not necessarily so, and further work is needed in this field before it is possible to reach definite conclusions.

A second test to be applied to a system of electrical insulation is an overpotential test. This is usually made after an insulation resistance test at lower voltages indicate that the insulation is clean and dry. Either a-c or d-c voltage may be used for overpotential tests. When the overpotential test voltage is d-c and of sufficient magnitude, it is sufficiently searching to pinpoint any insulation faults or damage which would be likely to cause breakdown in service with negligible probability of damage to sound insulation.[1]

Recent studies indicate repetitive application of high-potential d-c tests are not damaging to sound electrical machine insulation. Each successive a-c overpotential test reduces the life of the insulation.[8] These factors, plus the availability of small light-weight high-voltage d-c insulation testers, capable of making both insulation resistance and high-potential tests, are resulting in the extensive use of d-c tests to supplant a-c tests.[9]

The d-c tests, when performed on a regular basis and correlated with previously obtained data, will enable the maintenance specialist to detect impending weaknesses before they become serious enough to cause failure in service and may enable a far less expensive repair to be made.

## TEST RESULTS

THE TRACTION MOTOR UNIT was selected for concentrated testing, so most of the data presented is based on the armature units for traction motors. In general, all the armatures tested have approximately the same dimensional characteristics, although there are variations in copper size, copper arrangements in the slot, and the insulation types among the motors of various manufacturers. These variables apparently do not change the insulation resistance appreciably. The motors tested were designed for operating voltages of 1,000 and less. A typical traction-motor armature undergoing the d-c test is shown in Fig. 3. The overpotential test was combined with the insulation resistance test in the form of a series of 10-minute insulation resistance measurements at voltages from 500 volts up to the overpotential test voltage. The maximum d-c voltage applied

in the tests was 1.6 times the normal 1-minute a-c overpotential test voltage.

In order that the necessary test values may be recorded, a form of the general type as shown in Fig. 4 was used. This form provides for recording the microampere leakage current meter readings at 1/2-, 1-, 2-, 5-, and 10-minute intervals at various applied d-c voltages. A typical set of readings is included.

Fig. 5 shows test curves of insulation resistance as plotted for new armature windings. Fig. 6 shows similar tests on old windings of the same type as shown in Fig. 5. These windings had not failed and would normally be suitable for reconditioning and reusing on what is termed in the railroad industry as a "mileage overhaul." Accumulation of test data of this type on used armatures, using the instrumentation covered in this article, should permit the detection of some types of impending faults. A continued reduction of the 10-minute insulation resistance values, determined at regular mileage service periods, would be an indication of insulation deterioration. Surface leakage caused by an accumulation of conducting material on the armature surfaces providing leakage paths results in curves of the type shown by curve *1* of Fig. 7. This armature gave a test curve as shown in curve *2* of Fig. 7—after trichloroethylene vapor degreasing and a corn-cob blast cleaning. After vacuum impregnation in an insulating varnish, the insulation resistance curve of the armature was as shown in curve *3* of Fig. 7.

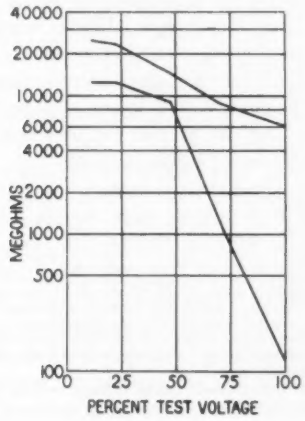


Fig. 6. Insulation resistance vs voltage curves for armatures removed at scheduled motor over-haul.

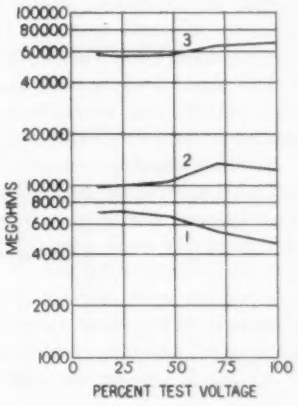


Fig. 7. Insulation resistance vs voltage for an armature: curve 1 is for armature as removed from motor to be overhauled; curve 2 is for same armature after trichloroethylene vapor degreasing and ground corn-cob blast cleaning; and curve 3 is for same armature after varnish and baking cycle.

The data for the curves mentioned were taken in an area where the line-voltage fluctuations were very erratic. This fluctuating input line voltage caused the d-c test voltage to vary above and below the average voltage impressed on the machine and the microammeter, indicating charging and discharging currents as variations occurred in the resultant d-c test voltage. The usual procedure is to record the average indicated value of a wavering meter pointer, and this is normally sufficiently accurate for this type testing in service application. However, in this case, two types of voltage regulators were available and were used—first, separately, and later in a series combination to provide maximum steadiness of the recorded values of meter readings.

## CONCLUSIONS

THE RAILROAD INDUSTRY, by widespread dieselization and electrification, is confronted with major problems in establishing electrical maintenance procedures which will reduce to a minimum train delays caused by electrical failures.

The use of d-c maintenance test procedures by the railroad industry is an effective method for improving control over electric outages caused by insulation failures. The d-c insulation test set described in this article is a suitable instrument for testing railway electric equipment.

It is the authors' conviction that by the use of high-voltage d-c insulation tests, the reliability of important electric transmission and traction equipment can be improved. It is hoped that the data presented will serve as a guide and encourage others to collect and present additional data, so that more extensive knowledge of the problem may be gained.

It is recommended that test procedures be studied intensively by the Land Transportation Committee with the objective of establishing a standard method of application of d-c tests on railway electric equipment.

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# Economic Comparison of Secondary Voltages

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THE HIGH COST of serving higher density residential loads with the conventional 120/240-volt radial system and the use of higher secondary voltages in commercial areas suggest that the potentialities of higher voltage systems should be studied for residential areas.

The purpose of this article is to present and compare the results of such studies with the results of studies of the conventional 120/240-volt radial system. The comparisons of the systems are based on optimized system costs.

System studies were made for a new residential area having approximately 14,000 houses. The studies were made for several average peak diversified demands, up to and including 10 kva per house.

The single-phase systems studied utilized 120/240-volt and 240/480-volt secondaries, and the 3-phase systems studied utilized 120/208-volt and 265/460-volt secondaries.

A subtransmission voltage of 34.5 kv was assumed to be available to serve the area. Large distribution substations were assumed to step down from 34.5 kv to the distribution voltage of 4.16 kv to supply the conventional 120/240-volt system. The 120/208-volt, 240/480-volt, and 265/460-volt systems were supplied directly at 34.5 kv. For the purpose of further comparison, the 120/240-volt system was also studied, assuming 34.5 kv as the primary feeder voltage.

A 3-wire house service was assumed for the 120/240- and 120/208-volt systems. For the higher voltage systems, 240/480 or 265/460 volts, a 2-wire service was assumed. An autotransformer was included in the service to each house served at 240 or 265 volts to provide 120 volts for lighting and convenience outlet loads. The higher single-phase voltage (240 or 265 volts) was assumed to serve all of the fixed high-wattage appliances, such as ranges, not served through the autotransformer.

Length of secondary circuits permissible at higher voltages made it practical to use an area coverage rather than a linear coverage. Hence, more load was served from one distribution transformer in the higher voltage systems. Significantly larger transformers at the higher voltage are used, with a lower cost per kva. Also, the total installed transformer capacity is lower at the higher voltage because of a gain in diversity.

The results of these studies are presented in Figs. 1 and 2. The curves in these figures show that both the 3-phase 265/460-volt system and the single-phase 240/480-volt system offer economies for the assumptions made.

Digest of paper 56-179, "Economic Comparison of Secondary Voltages, Single- and Three-Phase Distribution for Residential Areas," recommended by AIEE Committee on Transmission ann Distribution and approved by AIEE Committee on Technical Operations for presentation at AIEE Winter General Meeting, New York, N. Y., January 31–February 3, 1956. Published in AIEE *Power Apparatus and Systems*, August 1956, pp. 542–66.

R. A. Zimmerman and H. E. Lokay are with Westinghouse Electric Corporation, East Pittsburgh, Pa.

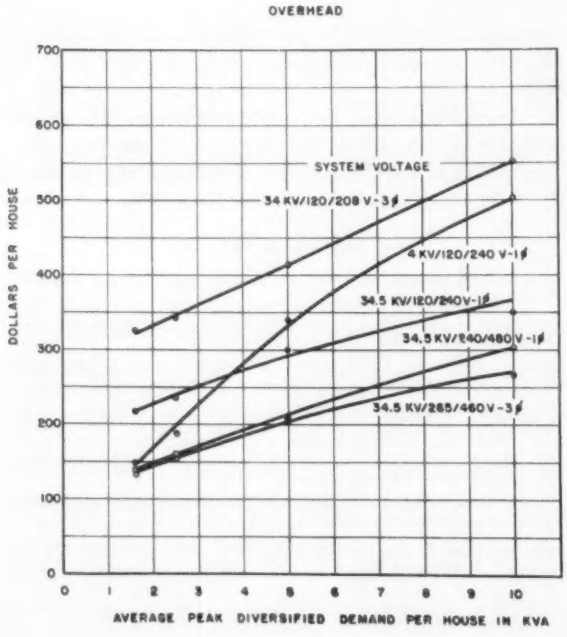


Fig 1 Overhead system investment in dollars vs average peak diversified demand—based on 1,000 houses.

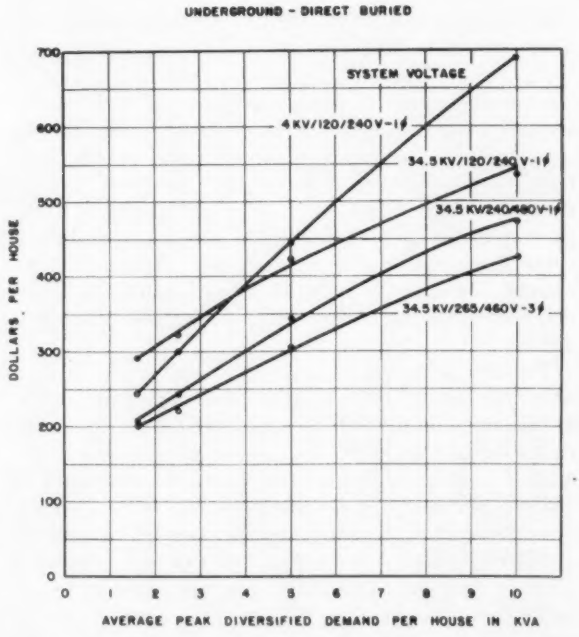


Fig. 2. Underground system investment in dollars vs average peak diversified demand—based on 1,000 houses.

# Use of Junction Transistors in Computer Amplifiers

W. A. CURTIN

AN INVESTIGATION has been conducted to determine the applicability of junction transistors to carrier frequency summing amplifiers of the type commonly used, for example, in the a-c analogue computers of military fire-control systems. The general form of the summing amplifier is shown in Fig. 1. Usually, large amounts of negative feedback are employed to maintain a high computing accuracy. The techniques used in the design of low frequency vacuum-tube feedback amplifiers are well known and so there is a tendency to determine if they are applicable to an equivalent transistor amplifier. Recognizing the transistor as the only new circuit element, a knowledge of its circuit behavior is essential. This paper, therefore, describes briefly some of the basic problems confronting the designer of transistor feedback circuits. The problems were investigated from both an analytical and experimental point of view and lead to the evolution of one design philosophy which yielded satisfactory results when applied to the design of an experimental 5-stage amplifier utilizing transistors which were commercially available in mid-1954. Typical transistors are the type *2N34* and newer type *2N109*.

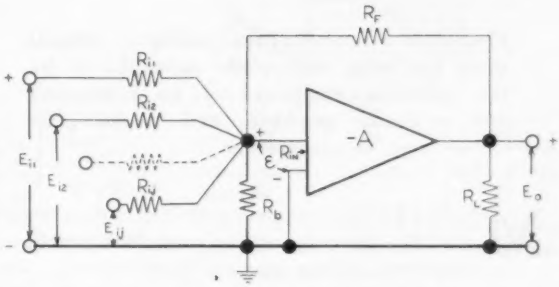


Fig. 1. General form of the linear parallel feedback amplifier.

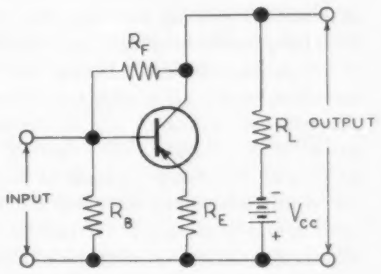


Fig. 2. Common-emitter amplifier with current and voltage feedback.

Preliminary to a discussion of those characteristics peculiar to transistor circuits, some of the important aspects of the circuit of Fig. 1 are considered. For summing amplifiers, the greatest concern is the dynamic accuracy and stability of the device. It is shown that the value of the design center loop gain required to maintain a specified maximum error is determined by how much the loop gain can vary. Variations of the loop gain are attributable to the nonuniformity of transistor characteristics, transistor aging, component tolerances, environmental conditions, and so on. A desirable situation, therefore, is to realize a low dynamic error with as low a value of loop gain as possible, since a large value of loop gain is troublesome from the point of view of stability. If the loop gain can be constrained to vary between narrow limits, the stability problem is reduced significantly. Hence, in order to determine how much loop gain is required, an investigation of the behavior of the transistor gain and terminal impedances is necessary. In addition, an examination of the amplitude and phase characteristics of certain transistor parameters is essential to the stability problem.

In particular, the magnitude variations and frequency characteristics of the current gain, input impedance, and transconductance have been investigated. The variations of these parameters was sufficiently large to make the loop-gain requirements prohibitive from the standpoint of stability. Therefore, in accordance with the preceding discussion, a means of minimizing the variation was sought. It has been found that local current and voltage feedback, or self-feedback, applied to each stage in the manner shown in Fig. 2 for the common-emitter amplifier, was highly effective in minimizing the variations. The effect of self-feedback on gain and impedance levels has been determined, and design equations for the common-emitter configuration have been derived which define transistor behavior in the presence of self-feedback. These equations are extremely useful for designing transistor circuits utilizing typical manufacturer's data. The phase shift of the transconductance is then shown to be the most important factor limiting the maximum available loop gain, a different situation from that which is normally encountered in the design of vacuum-tube amplifiers in the same frequency range.

An experimental 5-stage amplifier, based on the principles discussed, was designed. A maximum stable loop gain of 60 db is obtained. In the closed loop, the amplifier is capable of summing two 400-cycle input signals with unity gain, and has a 100 kilohms input impedance per input. The maximum error is $\pm 0.1$ per cent when the loop gain is subject to a 50 per cent variation. Stabilization against oscillation is effected using the simple resistance-capacitance networks commonly used in equivalent vacuum-tube devices.

Digest of paper 56-758 "Application of Junction Transistors in Carrier Frequency Computing Amplifiers," recommended by the AIEE Committee on Electronics and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, San Francisco, Calif., June 25–29, 1956. Scheduled for publication in AIEE *Communication and Electronics*, 1956.

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This article is abstracted from a thesis submitted to the Department of Electrical Engineering, Massachusetts Institute of Technology, in partial fulfillment of the requirements for the degree of Master of Science.

# A Delta-B Indicator

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**Control of magnetic characteristics of toroidal cores has been successfully accomplished by this indicator, comprised of an integrating and a linear amplifier, and peak-to-peak voltmeter.**

MANY TYPES of magnetic-amplifier circuits require that the toroidal magnetic cores used therein are uniform as to their magnetic characteristics. Also, in full-wave circuits, the two cores of a single-ended circuit and the four cores of a push-pull circuit require close matching among the cores of a specific unit.

A number of core-testing circuits have been devised to facilitate the grading and matching of cores, without the need for actually winding a considerable number of turns of wire around the core. During the "setting" phase of the operation, nearly all of such test circuits cause the rate-of-change of flux in the core to be at least an order of magnitude greater than it is during the "resetting" phase of operation. As a result, the voltage induced in the few turns of the "B" coil, commonly employed to indicate the flux change in the core, is highly distorted. It usually consists of a narrow peak of relatively high amplitude during the "setting" interval and a relatively low voltage lasting for the entire "resetting" interval.

When the "B" coil consists of only a few turns linking the core, the rectified average voltage induced in the coil is so low as to require a considerable amount of linear amplification by electronic means before its value can be indicated by a D'Arsonval-type of meter. The amplification of the highly distorted voltage waveform induced in the "B" coil of many core-testing circuits imposes severe requirements upon the electronic amplifier.[1] Most commercially available vacuum-tube voltmeters are unsatisfactory for use under such conditions. The delta-$B$ indicator described in this article was devised to overcome this difficulty.

## PRINCIPLES

IF THE OUTPUT VOLTAGE of the "B" coil is electrically integrated by means of a serially connected resistor and capacitor of suitable values, the waveshape of the voltage appearing across the capacitor will be the same as the waveshape of varying flux in the core under test. Since the maximum flux density change is limited by the saturation density of the core material, then, for a given core area and "B" coil, there will be a certain maximum peak-to-peak voltage across the capacitor of the integrator circuit regardless of the test frequency and the rate-of-change of flux in the core under test. This integrator voltage, therefore, can be amplified by a conventional linear amplifier without danger of overloading effects by excessive voltage peaks.

Now, since the peak-to-peak voltage of the integrated "B" coil voltage is proportional to the total flux change $\Delta B$ in the core under test, an indicating instrument capable of measuring this total swing will read proportional to $\Delta B$. The d-c voltage output of a voltage-doubler rectifier circuit is very nearly equal to the peak-to-peak value of the a-c voltage fed into the doubler rectifier. So if the amplified integrator output voltage is fed into a suitable doubler rectifier circuit, the d-c output voltage of the doubler will be directly proportional to the $\Delta B$ in the core under test.

## CIRCUIT

A SCHEMATIC DIAGRAM of a $\Delta B$ indicating circuit employing these principles is shown in Fig. 1. Starting from the INPUT terminals, across which the "B" coil is connected, the first two tubes, $T_1$ and $T_2$, and associated circuitry comprise a so-called Miller-type of integrating amplifier, which is equivalent functionally to an R-C voltage integrator and subsequent amplifier. The cathode-follower-connected $T_2$ tube eliminates the loading effect upon the plate circuit of the amplifier tube of the 0.015-microfarad feedback integrator capacitor $C_1$. In the Miller-type of integrator, the effective integrating capacitance is the product of the feedback capacitance and the gain of the amplifier. For the circuit constants used in this integrating amplifier, the gain of the amplifier is approximately 70, hence the effective integrating capacitance is approximately 1.05 microfarads. The time constant of this, in combination with the 240,000-ohm input resistor $R_1$, is therefore approximately 0.25 second.

The integrating amplifier is followed by a high-gain linear amplifier consisting of the two halves of a *12AX7* tube, $T_{3A}$ and $T_{3B}$, and another cathode-follower output tube $T_4$. The gain of this amplifier is stabilized by means of inverse feedback provided by the 240,000-ohm resistor $R_2$ and 0.5-microfarad blocking capacitor $C_2$.

The output voltage of the cathode follower tube $T_4$ is fed into the peak-to-peak voltmeter circuit. This voltmeter circuit consists of the two *1N92* diodes, the two 1.0-microfarad capacitors, $C_3$ and $C_4$, and the 0–2 microampere meter $I$, with adjustable series resistance $R_3$ for adjusting the calibration of the voltmeter. The capacitor $C_3$ between the cathode of tube $T_4$ and the first diode serves the dual function of blocking the d-c voltage across the 50,000-ohm output resistor $R_4$ of the cathode follower and providing one

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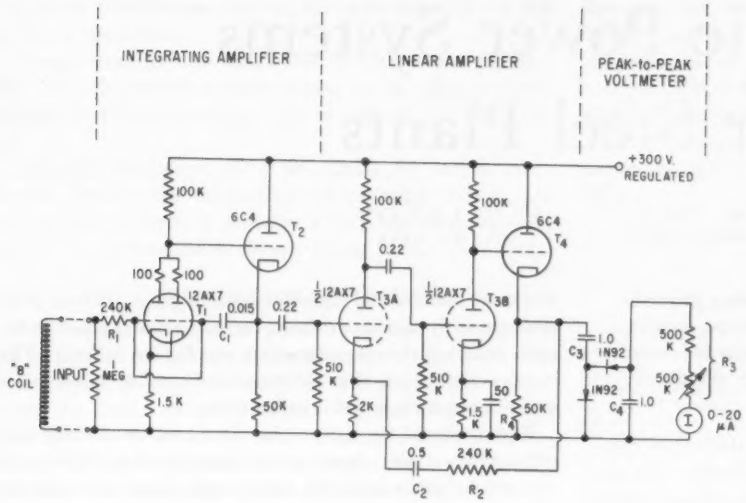
The assistance of P. A. Fessler and H. S. Lasher in the development of the device is gratefully acknowledged.



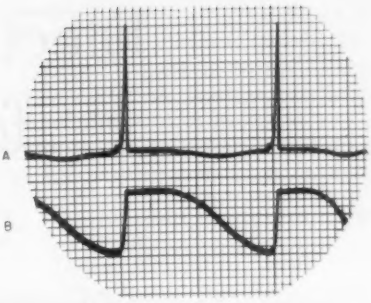




Fig. 1 (*left*). Schematic circuit diagram of the delta-B indicator. Fig. 2 (above). Typical voltage waveforms

*Curve A: Induced voltage in "B" Coil with core under test. Curve B: Output voltage of integrating amplifier with Curve A voltage as input*

of the capacitors of the voltage-doubler rectifier circuit.

### WAVE FORM

An indication of the extent to which the integrating function of the delta-$B$ indicator converts the highly peaked voltage wave to a wave form, which readily can be amplified, is had by comparing the wave shapes shown by Fig. 2. Curve $A$ of Fig. 2 is an oscillogram of the voltage induced in the "B" coil of a Dynamax core under test in a circuit, which employs a half-cycle sinusoidal "setting" current and a constant direct current from a high-impedance source for "resetting." When the highly peaked voltage of curve $A$ is impressed upon the input terminals of the delta-$B$ indicator, curve $B$ of Fig. 2 shows the voltage which appears at the output of the integrating amplifier. Curve $B$, the integral of curve $A$, is indicative of the shape of the variation in flux density in the core under test. Since the "setting" current always saturates the core in the direction shown as a positive deflection of curve $B$, the saturation density of the core material under test provides a fairly reliable reference for this curve of flux density versus time. The steepness of the positive-going portion of curve $B$ indicates the rapidity with which the flux density is brought to saturation density by the "setting" circuit. It is the high rate-of-change of flux at this portion of the wave of core flux which induces the peak of voltage in the "B" coil.

In order that the readings of the indicating microammeter be related to the $\Delta B$ of the core under test, a sinusoidal voltage of known frequency is used to obtain a calibration curve of the relation between the quotient of the rectified average input voltage $E_{av}$, divided by frequency $f$, and the indicating instrument $I$, reading in microamperes. This is possible since the integrating circuit makes the quantity $E_{av}/f$ a constant, regardless of frequency, for any given value indicated on the peak-to-peak voltmeter. Then, since

$$\Delta B = \frac{E_{av}}{f}\,\frac{10^8}{2AN}$$

where $A$ is net core area and $N$ is the number of turns on the "B" coil, the $\Delta B$ for a certain value of indicated current can be calculated. The same calibration can be used for all test frequencies within the frequency range of the linear amplifier.

### USES

This delta-$B$ indicator has been used successfully in core matching and grading test gear of the Aeronautics Ordnance Systems Department of the General Electric Company. Their engineers report that they have incorporated this device in core testers in their laboratory and in their manufacturing facilities. Also, one of their core suppliers has duplicated their testers for controlling the quality of the core supplied to them by that vendor.

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## Ultrasonic Tire Tester

Uniformly high standards of quality in the manufacture of new tires and considerable savings in retreading operations can be achieved with an ultrasonic testing device introduced by the Industrial and Scientific Products Division of the Curtiss-Wright Corporation, Caldwell, N. J. The ultrasonic tire tester locates and measures flaws in new or used automobile, bus, truck, and aircraft tires through the use of silent, invisible, nondestructive beams. Even such obscure imperfections as minute blisters and tread separations are reported on an indicator, permitting rejects of castings with flaws larger than a predetermined size. Simplicity of operation is an outstanding feature of the compact equipment. Testing is accomplished by immersing a tire in a liquid bath containing a transmitter which directs an ultrasonic beam through the tire to a receiving sound-head suspended inside the casing.

# Electric Power Systems for Steel Plants

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**In view of the nature of the steel-making process, a high degree of reliability in electrical service is absolutely essential. The problems involved in steel-plant electric systems are discussed.**

THE STEEL INDUSTRY is one of the largest industrial users of electricity in the United States. The electrical problems encountered range through generation, transmission, distribution, and utilization.

The annual production of steel in the United States in 1955 was 116 million ingot tons. The electric energy used by the steel industry during this same year was 27 billion kwhr. This corresponds to about 232 kwhr per ingot ton of production.

The nature of the steel-making process is such that a high degree of electrical service reliability is required in some areas to avoid consequential damage. In all areas, loss of production caused by electric outages makes it necessary that a high degree of service reliability be designed into the system.

## PLANT LAYOUT

INDIVIDUAL PLANTS vary widely depending upon the nature of the terrain and the historical growth pattern. The plant layout, load magnitude, and distribution are important factors in selecting the proper voltages and in designing the electrical distribution system. The nature of some of these factors can best be illustrated by an example. Fig. 1 is a layout of a hypothetical integrated steel mill which will be used for discussion purposes. This mill is located near a river or lake which provides low-cost transportation for raw materials and adequate water supplies for cooling furnaces, condensers in the powerhouse, and other miscellaneous uses. The powerhouse is located close to the blast furnaces to reduce the distance the blast-furnace gas must be transported to provide fuel for the powerhouse boilers, and to reduce the distance over which the steam for the blast furnace turboblowers must be piped.

The flow of material is as follows:

1. Raw materials are loaded into the blast furnace.
2. Pig iron from the blast furnaces, and scrap are put into the open-hearth furnaces.
3. Steel from the open hearth is poured into ingot molds.
4. Ingots are transported to the soaking pits to provide proper and uniform temperature of the ingots for rolling.
5. Ingots from the soaking pits are fed into the mills.

Coke is obtained for the blast furnace by heating coal to a high temperature for a few hours in coke ovens. This drives off the tars and high-Btu-content gases. These gases are frequently mixed with blast-furnace gas and piped to the open hearth furnaces and soaking pits for use as fuel. The residue of the coal, after the gases and tars are driven off is almost pure carbon and is called coke.

Raw material for the arc furnaces consists of scrap and refining materials. Some plants supply molten pig iron to the arc furnaces and add scrap and other materials required to make the desired grade of steel. This is known as a hot metal charge. The power supply for the arc furnaces usually is segregated from the other loads to minimize voltage flicker problems.

## ELECTRIC ENERGY GENERATION

IT IS THEORETICALLY POSSIBLE for a well-balanced integrated steel mill with modern facilities and efficient practices to produce all of the electric power required for the various processes from the waste heat and by-product fuels available from the process.

Coal is the primary fuel. Blast-furnace gas, coke-oven gas, and waste-heat boilers on the open hearth furnaces are the principal sources of by-product fuel and heat energy utilized. The blast furnace requires more fuel than any of the other process units in the plant, and provides the largest surplus of by-product fuel, which can be used for power generation.

A blast furnace can be expected to produce about 120,000 cubic feet of gas per ton of pig iron produced. There will be some variation of this figure depending upon the quantity of coke used per unit of output. The gas is lean, averaging about 90 Btu per cubic foot; consequently, it has a large volume per unit heat content. For this reason, it is desirable to use it close to the source.

From 25 to 30 per cent of this gas will normally be used in the stoves for preheating the air to the blast furnaces. Another 25 to 30 per cent will be used for other purposes, principally furnace blowing, soaking pits, reheating furnaces, losses, etc., leaving from 40 to 50 per cent for the generation of electric power. Assuming a 25 per cent station heat rate, this indicates that for each ton of pig iron produced, from 316 to 394 kwhr of electricity could be produced. Inasmuch as each ton of ingot normally contains about 0.73 ton of pig and 0.27 ton of scrap, on the average, this indicates that in terms of ingot tons of steel produced

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**H. N. Cox** and **L. G. Levoy** are with the General Electric Company, Schenectady, N. Y.

the excess blast-furnace gas can generate from 230 to 288 kwhr per ingot ton.

Thus, a modern blast furnace rated 1,500 tons of pig iron per day will provide enough excess gas to generate from 475,000 to 594,000 kwhr per day or from 19,750 to 24,700 kw.

Although this excess gas is not salable for normal commercial distribution because of the excessive volume per unit of heat content, it provides a very attractive low-cost fuel for the generation of electric power by the steel plant.

## ELECTRIC ENERGY CONSUMPTION

THE AMOUNT OF ELECTRIC ENERGY required to produce a ton of finished steel varies widely and depends upon whether it is produced by open-hearth or electric furnaces, and upon the final finished product. Typical figures range from 200 to 300 kwhr per ton. Electric-arc furnaces require from 500 to 600 kwhr per ton starting with a cold scrap charge. The increasing use of arc furnaces will tend to increase the average amount of electric energy per ton of finished steel.

In an integrated plant that produces steel from raw materials in blast and open-hearth furnaces (no electric-arc furnaces) the power consumption will vary from 200 to 250 kwhr per ingot ton of steel produced, when the ingots are rolled into a well-distributed list of finished products.

Table I lists some average power requirements for different types of rolling mills and includes all auxiliary a-c and d-c power as well as the main work roll drives. These are listed only to give a rough idea of the power requirements of different types of mills. A more accurate calculation of power requirements can be made for a given case when the particular alloy and range of products to be rolled is known.[1, 2, 3]

**Table I**

| Process | Kwhr per Ton of Product |
|---|---|
| Coke plant | 17* |
| Blast furnaces | 10† |
| Open hearth | 8‡ |
| Blooming or slabbing mill | 20 – 25 |
| Plate mill | 30 – 40 |
| Hot strip mill | 80 – 90 |
| Cold strip mill | 80 – 100 |
| Billet mill | 20 – 30 |
| Rod or bar mill | 60 – 80 |
| Structural and rail mills | 30 – 60 |
| Continuous pickling | 6 – 7 |
| Electrolytic cleaning | 8 – 9 |
| Tin-mill annealing | 15 – 20 |
| Tin-mill temper rolling | 15 – 20 |
| Electrolytic tinning | 90 – 110 |
| Sheet-mill galvanizing | 25 – 30 |

* Kwhr per ton of coke produced.

† Kwhr per ton of pig iron.

‡ Kwhr per ton of steel ingots.

A plant may have more or fewer of such processes as listed in Table I, depending upon the products made. In addition to these loads, a typical plant has pumps, shops, air compressors, yard and office lighting, and other miscellaneous loads which increase the total power consumption.

The figures in Table I represent average power requirements only. Due to the nature of the various loads and their diversity, the demand will exceed the average. In a typical integrated steel plant, records indicate that the 15-minute demand is 50 per cent over the average, the one-hour demand is 32 per cent over the average, and the eight-hour demand is 22 per cent over the average.

Table II indicates the range of main drive horsepower requirements which are typical of those found in modern mills.

**Table II**

| Type | Total Main Drive Horsepower on Work Rolls |
|---|---|
| Blooming or slabbing mills | 8,000 – 12,000, d-c |
| Hot strip mill roughing train | 12,000 – 20,000, a-c |
| Hot strip mill finishing train | 20,000 – 30,000, d-c |
| Tandem mill | 15,000 – 25,000, d-c |
| Bar or rod mills | 5,000 – 10,000, d-c |

In addition to the types of mills mentioned here, there are many miscellaneous types and combinations.[1]

## GENERAL POWER SYSTEM REQUIREMENTS

THE STEEL INDUSTRY, like most other modern industries, is unable to produce efficiently without the aid of electricity. The important thing to remember when designing the electric system for a steel plant is that a typical medium size plant may have an annual output of 2 million tons per year or about 5,500 tons per day, valued at approximately $550,000 per day. Obviously the loss of even one hour of production is costly and to be avoided if at all possible. The cost of electric energy and the equipment that distributes this power is so small in comparison to the value of the product being produced (or not being produced because of power failure), that nearly all steel companies insist on using the most reliable electric equipment that is available. Efficiency is important for economy reasons, but reliability is of paramount importance.

Another reason why power failures are to be avoided insofar as feasible is the possibility of contingent damage to equipment, resulting from a nonscheduled power loss. The cooling water supply to a blast furnace is an example of a service which requires the utmost in service reliability. Loss of cooling water for even a short time can result in loss of the furnace and extremely costly repairs. Consequently, such services should have duplication of equipment from the water pumps back through the system to the primary sources of power. Hot metal or ladle cranes and blast furnace skip hoist motor-generator sets are other examples of loads that should be supplied with two or more independent sources of power. This principle of duplication of power channels should be used in all areas where a high degree of service continuity is required.

The dirty atmosphere around many steel mills results in another consideration in the electric power system design; that is, where insulators are exposed to the dirty atmosphere, high-creepage insulators are used. Examples of this are extra disks in suspension insulators, and additional creepage length on outdoor transformer and switchgear bushings. This extra creepage path does not eliminate

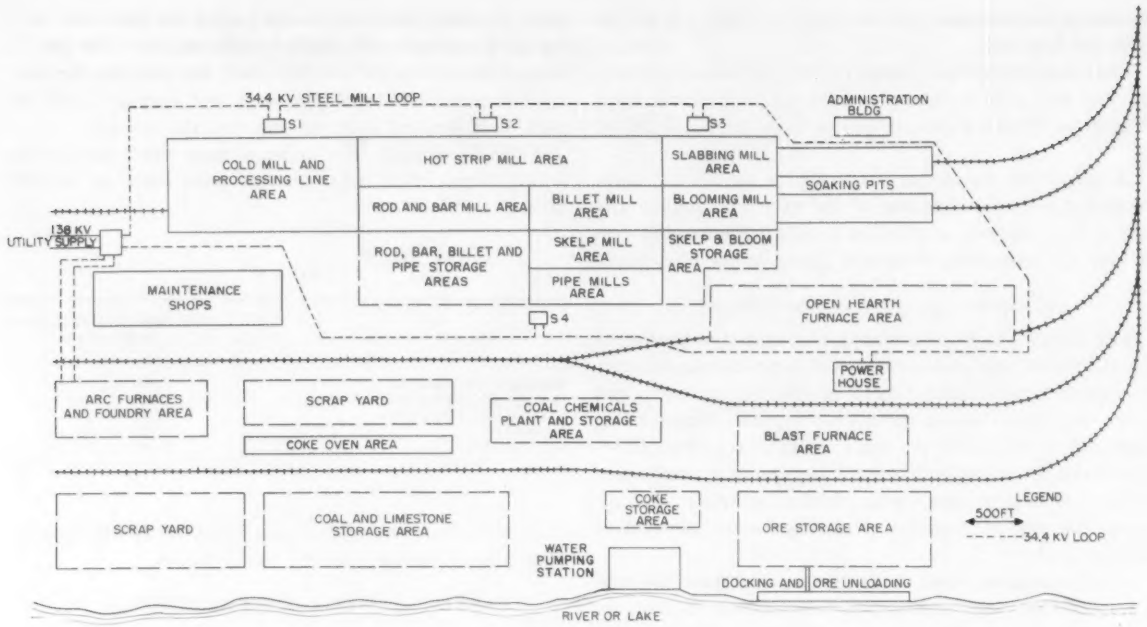


Fig. 1. Layout of an integrated steel plant.

the necessity for a regular cleaning program, but does lengthen the time interval between required cleanings.

Inside the mill buildings, motor rooms are provided which house the switchgear and control equipment for the main motors. These rooms are supplied with filtered and cooled air to provide a suitable environment for this equipment. Fig. 2 illustrates the motor room in a modern cold strip mill, showing the main drive motors and control.

## DESCRIPTION OF A TYPICAL ELECTRIC SYSTEM

MANY OF THE DESIGN PRINCIPLES and techniques can best be illustrated by an example. Fig. 3 is a one-line diagram of the primary power system for the mill layout shown in Fig. 1, and illustrates one way that such a plant could be served.

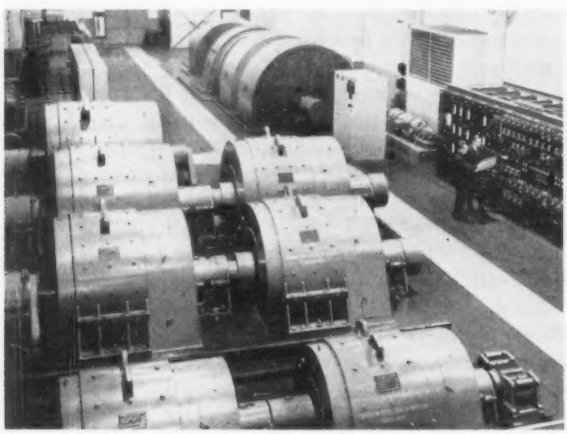

Fig. 2. Motor room in modern cold-strip mill.

In this arrangement, the utility is assumed to supply two 138-kv incoming lines. Two steam turbine generators are shown for the power house. These units supply part of the electric power for the mill. Blast-furnace gas is used as a fuel for the boilers, supplying steam for the turbine generators.

A 34.4-kv primary loop circuit is used, for illustration purposes, in Fig. 3 to distribute power to the stepdown substations in the mill areas. Power is fed into this loop from the utility on one end and by the two plant generators on the other end, thus providing four sources of power for the loop. Reserve capacity is provided so that loss of any one generator, transformer, or primary circuit would not limit production. The 34.4-kv loop primary provides a high degree of service reliability to all substations. Load tap changing is provided on the utility tie circuit transformers to maintain essentially constant voltage on the 34.4-kv system and permit proper division of reactive kva between plant generators and utility. The transformers are connected delta-wye to provide for grounding on the 34.4-kv side.

The selection of voltage and the circuitry for the primary power distribution is frequently dictated, at least in part, by the historical growth pattern of the plant. It is possible to serve plants of this size or even larger at 6.9 or 13.8 kv without the use of higher voltage subtransmission circuits, but such systems do not usually provide the economy and flexibility for future growth that can be realized by using a higher voltage subtransmission system.

The voltage for the subtransmission circuit should be selected, in any given case, at the level which provides for economical system design. Transmission circuits and associated equipment should have adequate reserve for emergency operation as required, and the system should be

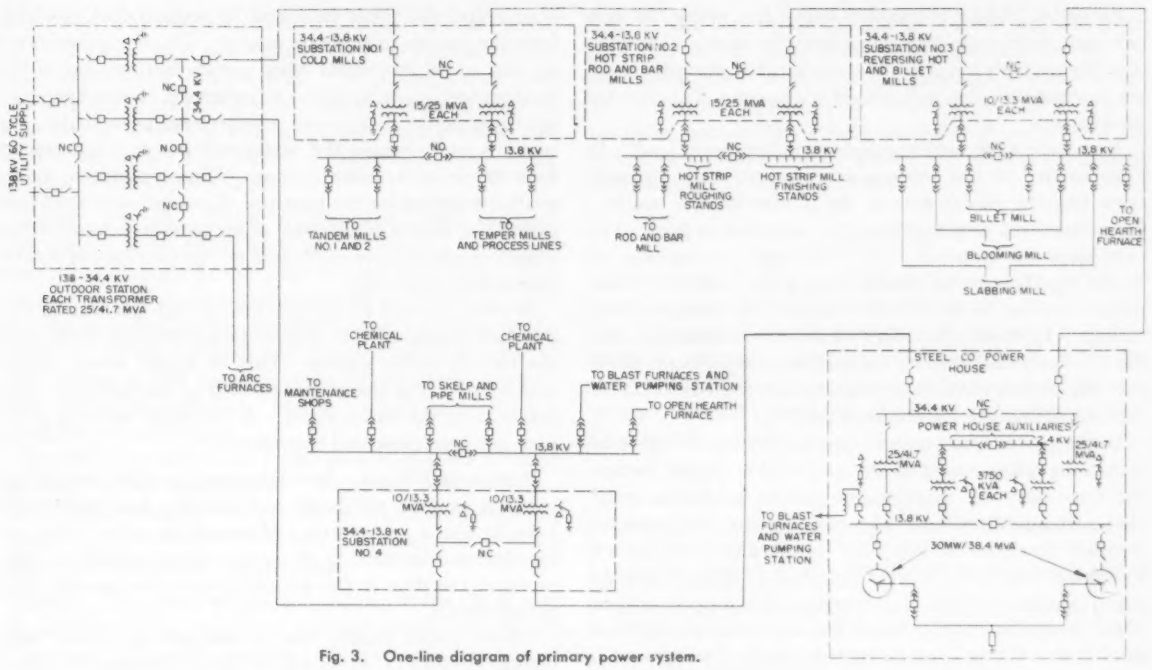
138 KV 60 CYCLE UTILITY SUPPLY
34.4 KV
NC
NO
138 - 34.4 KV OUTDOOR STATION EACH TRANSFORMER RATED 25/41.7 MVA
TO ARC FURNACES
34.4-13.8 KV SUBSTATION NO.1 COLD MILLS
15/25 MVA EACH
13.8 KV
TO TANDEM MILLS NO. 1 AND 2
TO TEMPER MILLS AND PROCESS LINES
34.4-13.8 KV SUBSTATION NO.2 HOT STRIP ROD AND BAR MILLS
HOT STRIP MILL ROUGHING STANDS
HOT STRIP MILL FINISHING STANDS
TO ROD AND BAR MILL
34.4-13.8 KV SUBSTATION NO.3 REVERSING HOT AND BILLET MILLS
10/13.3 MVA EACH
BILLET MILL
BLOOMING MILL
SLABBING MILL
TO OPEN HEARTH FURNACE
TO CHEMICAL PLANT
TO MAINTENANCE SHOPS
TO SKELP AND PIPE MILLS
TO BLAST FURNACES AND WATER PUMPING STATION
TO OPEN HEARTH FURNACE
34.4-13.8 KV SUBSTATION NO. 4
STEEL CO POWER HOUSE
POWER HOUSE AUXILIARIES
4 KV
25/41.7 MVA
3750 KVA EACH
30MW/38.4 MVA
TO BLAST FURNACES AND WATER PUMPING STATION

Fig. 3. One-line diagram of primary power system.

flexible for future growth. A higher subtransmission voltage such as 69 kv would probably be used if the plant were larger, requiring longer transmission lines and heavier loads. In big plants, multiple subtransmission circuits are frequently used to provide improved reserve capacity and service reliability.

In situations where the utility requires that the 138-kv winding be grounded, wye-delta-wye transformers can be used to permit grounding on both sides. Lightning arresters, relays, and surge protective equipment have been omitted from this diagram for simplification.

In the normal operation of the plant shown in Fig. 3, the arc-furnace load is segregated from the other mill loads by use of separate 138/34.4 kv transformers. This arrangement minimizes the voltage flicker disturbances on the circuits feeding the other mill loads. A normally open tie breaker is provided between the arc furnace and mill loop supply busses at the 34.4 kv level for flexibility of operation in the event of a transformer outage.

Each of the four substations is provided with 34.4/13.8 kv stepdown substations to provide power at 13.8 kv to the various mill areas. The 34.4-kv tie is operated normally closed at each substation to provide dual channels for power flow to all stations under normal operating conditions. All 13.8-kv busses (except the power station bus) in this system are laid out for use with standard metal-clad switchgear of 500-mva interrupting capacity. A bus-tie circuit breaker is provided in each 13.8-kv substation bus. It is desirable to operate with this circuit breaker closed in cases where closing it will not cause the fault levels to exceed the 13.8-kv switchgear rating. Whether or not this circuit breaker is operated normally closed depends upon the size and impedance of the supply transformers and the characteristics of the connected load.

For example, in Fig. 3 the 13.8-kv bus-tie circuit breaker in substation no. 1 is shown normally open because these mills are normally driven by d-c motors supplied from synchronous motor driven motor-generator sets which will contribute substantially to the fault duty on these busses. However, in substation no. 2 the 13.8-kv bus tie is shown normally closed even though the same size transformers are used. In this case, the hot strip mill finishing stands are driven by d-c motors supplied from power rectifiers which do not contribute to the fault duty on the bus, thereby making it possible to operate with the bus tie closed, even though the roughing stands and bar mill motors do contribute to the fault duty.

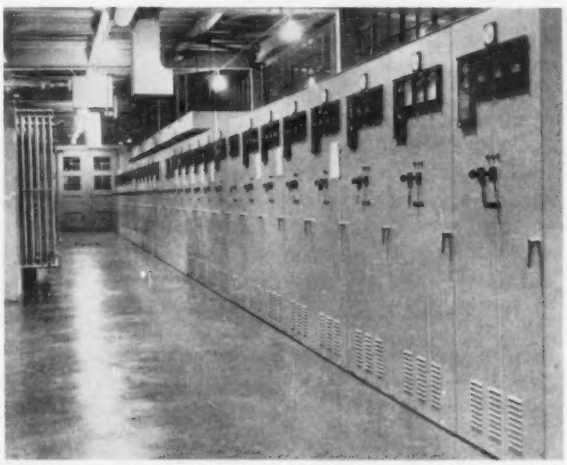

Fig. 4. Lineup of modern 13.8-kv metal-clad switchgear.

Recently, 13.8-kv metal-clad switchgear rated 750 mva has been developed, thus permitting the design of systems with higher fault levels in cases where this is warranted, and yet maintaining the well-known advantages of metal-clad switchgear.

Two feeders are used to supply each important load. In cases where the bus sections are operated with normally open ties, the two feeders to the subdistribution bus in a given load area originate from the same bus section. This eliminates the possibility of accidentally connecting the busses together at the subdistribution bus with the consequent increase in fault levels beyond the circuit-breaker ratings. In those substations which can be operated with the 13.8-kv bus-tie circuit breaker normally closed, duplicate feeders to a given load area originate from different bus sections to improve the service reliability.

In the powerhouse, cubicle-type switchgear of higher interrupting rating is used on the main 13.8-kv busses, because the fault duty on these busses exceeds available metal-clad switchgear ratings. The power plant auxiliaries are supplied by means of stepdown transformers as indicated. For power which is to be used nearby at 13.8 kv, such as the feeder shown for the blast-furnace and water-treatment plant, a current limiting factor is used to reduce the fault duty so that 500-mva metal-clad switchgear can be used in such areas. For larger power plants containing more generating units, a synchronizing bus arrangement may be used to limit the fault duty.

## D-C SYSTEMS

MAIN DRIVE MOTORS are usually designed either for 600-, 700-, or 750-volt operation. It is normal practice to operate these d-c systems ungrounded. On large common bus systems, fault levels tend to become excessive; consequently, many modern large high production mills use the individual generator or rectifier system. Although this results in a lack of diversity on the sources, so that full source capacity is required, it does not necessarily mean that any less would have been provided on a common bus. The use of the individual generator or rectifier system results in a substantial saving in low-voltage bus and switchgear, and brings the d-c fault levels down to acceptable values.

Steel mills usually require a reliable 250-volt constant-potential d-c source for the operation of cranes, screwdowns, coil handling equipment, etc. Prior to 1940, this power was usually furnished by means of motor-generator sets. Improvement in design of rectifiers has made them a reliable source of power for this service and they are being used in most of the recent installations. Some of the advantages of rectifiers as compared with motor-generator sets for this service are lower installation cost, less maintenance, and higher efficiency.

## TRENDS IN STEEL PLANT ELECTRIC SYSTEMS

There appear to be certain trends which are discernible in steel mill electric systems and equipment as these systems evolve through experience and availability of improved designs. Some of these are as follows:

*Generated vs Purchased Power.* The trend today, which is the result of many economic studies made by various plants, is to utilize the waste heat and by-product fuel available from the process to generate power. This is supplemented by coal or oil in periods when a sufficient amount of by-product fuel is not available to utilize the installed generating equipment. For power requirements beyond this, the trend is to purchase the additional power requirements from the electrical utility system. This arrangement makes available capital for the purchase of new efficient steel production or rolling equipment, or for plant expansion which otherwise would have to be used for the purchase of power-generating equipment.

A natural result of the practice of both generating and purchasing power is a tie between the steel plant system and the electric utility system. This tie brings about certain problems such as the proper sharing of kilowatts and kilovars among the two systems. A discussion of these problems has been presented elsewhere.[4, 5]

*Selection of Voltages.* It is important to select the proper voltages to serve the loads economically and provide for possible future expansion. Many of the older mills are handicapped by starting off with a voltage which was adequate at the time it was selected, but is too low for their present size.

Larger plants usually find it desirable to have a high voltage circuit such as 34.4 or 69 kv to distribute the power to spot loads on the site and then transform down to 13.8 kv for utilization at these load centers. The circuits shown in Fig. 3 illustrate this type of system. This plant is relatively compact and it would be possible to serve it at 13.8 kv. If the plant were spread out, requiring longer transmission circuits between spot leads, 34.4 kv would show greater economic advantage. For a larger plant requiring still more power and greater transmission distances, 69 kv would be economical. Because of the size of load involved, the tie with the utility system often is made at 115 or 138 kv.

Although 6.9 kv has been used extensively in the past as a utilization voltage for large motors in steel mills, there is a trend toward the use of 13.8 kv, because the switchgear ratings available make it possible to handle more load at 13.8 kv than at 6.9 kv without exceeding the momentary rating of the circuit breakers. For picking up a larger load at some distance and reducing cable costs for serving large loads, 13.8 kv also provides greater flexibility. The disadvantage of 13.8 kv as a utilization voltage is that motors in the 2,000–15,000-hp range cost more at 13.8 kv than they do at 6.9 kv.

Economic studies in many steel mills have indicated that the following choice of motor voltages provides a flexible and economic system:

| System Voltage | Motor Voltage | Motor Horsepower |
|---|---|---|
| 13.8 kv | 13.2 kv | 2,000–15,000 |
| 2.4 kv | 2.3 kv | 200– 2,000 |
| 480 volts | 440 volts | 200 and below |

Exceptions will occur in which it will be desirable to deviate from this guide, depending upon the length of circuit required to serve the motor at the preferred voltage.

*Medium-Voltage Switchgear.* The 13.8-kv switchgear nor-

mally used in modern steel mills is of the metal-clad vertical lift or drawout type and is oilless, thereby eliminating the disadvantages and hazards of oil. Very often these circuit breakers are located indoors in a motor room. However, they can be provided with a weatherproof housing and located outdoors. Fig. 4 shows a lineup of modern indoor 13.8-kv metal-clad switchgear.

*System Complexity.* Older systems were often designed with many possible routes for power to flow to a given load, with the intention of improving service reliability. This practice resulted in relatively complex systems with complicated operating rules to avoid excessive fault duty on the breakers. Many accidents and failures have occurred in such systems as the result of errors in switching, particularly during emergencies. Simple systems minimize the possibility of such errors.

Improved apparatus and cables have eliminated the need for much of this complication. The trend today is to obtain service reliability by the use of high-quality components carefully installed in relatively simple circuits which are easy to understand and operate.

*Safety.* The use of metal-clad switchgear has eliminated the need for many disconnect switches which were always a source of danger to operators. There is a definite trend away from the indiscriminate use of disconnect switches in the interest of safety and improved service reliability.

*Grounding Practice.* The advantages of a-c system neutral grounding at all voltage levels is being recognized. Many existing plants have changed from ungrounded to grounded neutral operation and most new installations are planned for neutral grounding. It will be observed from Fig. 3 that the 13.8- and 2.4-kv systems are resistance grounded to minimize possible burning damage on the motors connected to them, and yet provide selective relaying of faulted circuits. The 480-volt system is solidly grounded since at this voltage level the impedance of the ground return path usually is sufficient to limit the ground fault current to acceptable values.[7]

## CONCLUSION

HISTORICALLY, the steel industry has been quick to recognize new electrical developments and put them into use. Progress in electric systems and components is continuous. Increased production requirements and the trend toward further automation in the future will further increase the requirements for improved and expanded steel plant electric systems.

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# Laboratory Program Devoted to Butyl Research

Enjay Company, Inc., a marketer of petrochemicals, recently unveiled its new Polymer Laboratory in Linden, N. J. It is equipped with the newest and most advanced facilities in the field of rubber technology.

Most of the laboratory's program will be devoted to applications research work on Butyl, the synthetic rubber manufactured from refinery gases, and to adapting Butyl to industrial needs. Butyl's special air-retention properties and its resistance to aging and the effects of chemicals and oxidation have led to its use in some 200 other products—about 100 of these are automobile parts. As a result of further advances in Butyl research, announcement was made of progress in the development of all-Butyl passenger-car tires.

The lab has 24 major pieces of equipment, plus another score of testing devices. In one testing apparatus—an ozone chamber (right)—Enjay researchers can duplicate atmospheric conditions to be found anywhere in the world. These tests are of unusual importance because ozone normally cracks, and eventually breaks down, both natural rubber and most synthetics. Butyl is about 500 times as resistant to deterioration as the natural rubber.

# Propagation Test on Microwave Communications Systems

H. R. MATHWICH  E. D. NUTTALL (MEMBER AIEE)  J. E. PITMAN  A. M. RANDOLPH (ASSOCIATE MEMBER AIEE)

**In the Gulf South area, investigations were made to obtain data on three different frequency bands, practical for use in a microwave communications system. Propagation difficulties, such as humidity variations and temperature inversion were investigated.**

THE RAPIDLY EXPANDING NEED for communications by United Gas Pipe Line Company, Shreveport, La., indicated the need for an examination of the communications medium, microwave relay. Work by Bullington,[1] Crawford and Jakes,[2] Durkee,[3] Millar and Byam,[4] Thompson,[5] and others provided valuable information for system planning and operation in most areas of the United States. In the Gulf South area, locale of United Gas' operations, microwave propagation information was not available. Rumors, difficult to prove or disprove, were current concerning the propagation difficulties encountered by early systems in the area. In this almost subtropical section of the country, humidity variations were known to be high. Temperature inversion also had to be considered. Previous observations of vhf systems and a test at 960 mc indicated the possibility of unusual conditions at the higher frequencies of 2,000 and 6,700 mc. Investigation by the research department of United Gas revealed the interest of microwave manufacturers in the propagation problems of the area. A test was designed to accumulate data on three of the frequency bands available to pipeline companies. It was planned to operate circuits at 955.5 mc, 1,965 mc, and 6,730 mc over the same path for a period of time long enough to provide statistical data. United Gas, as the prime contractor, arranged for Philco Corporation to furnish certain equipment and services for the 6,730-mc frequency. By separate arrangements with the Radio Corporation of America (RCA), equipment and services related to 955.5- and 1,965-mc frequencies were made available. The results of the ensuing test are reported in this article. Its purpose is not to judge the relative merits of the three frequency bands involved, but rather to make the accumulated data available to the literature on the subject. It must be constantly borne in mind in the interpretation of the data presented that the tower heights and resulting path clearances were not considered optimum for any of the three frequencies being tested.

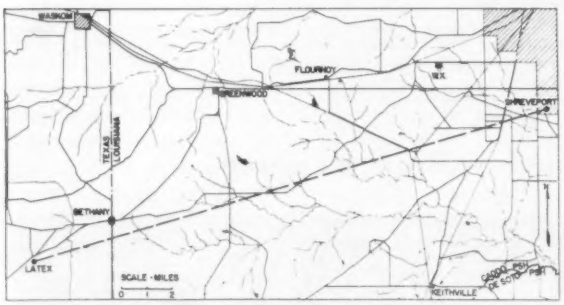


Fig. 1. Strip map of test path.

## DESCRIPTION OF TEST

TEST CIRCUITS were set up between the United Gas Research Laboratory, Shreveport, La., and one of the company's compressor stations at Latex, Tex., a distance of 20.25 miles. A strip map of the path is shown in Fig. 1, and a profile drawn to true earth radius is shown in Fig. 2. The survey of the path was made by plotting the profile from geodetic maps, which were available from Shreveport to the Louisiana–Texas border. The balance of the path was plotted from hand altimeter readings taken along the path survey line from the Louisiana–Texas border to Latex. All high points along the path were later rechecked by sensitive altimeter for accuracy. Tree covering along the path ranged from sparse to moderately heavy, principally deciduous with a few pine. Tree heights were determined on the high points of the path by measuring the height of the tallest tree in the group under consideration.

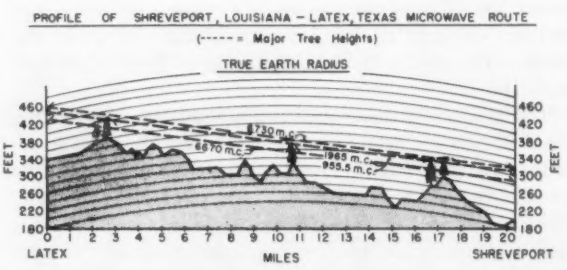


Fig. 2. Profile map of test path.

Full text of paper 56-968, "Propagation Test on 955 Mc, 1,965 Mc, and 6,730 Mc," recommended by the AIEE Committee on Radio Communications System and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Fall General Meeting, Chicago, Ill., October 1–5, 1956. Scheduled for publication in AIEE *Communication and Electronics*, 1956.

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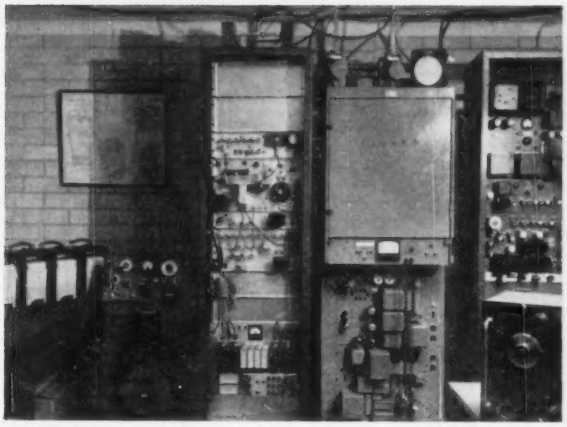

Fig. 3 *(left)*. Shreveport antenna installation. Fig. 4 *(above)*. Shreveport radio-equipment installation.

No sizable streams or bodies of water were under the path. From Fig. 2, it should be noted that the path is roughly grazing at three points.

The test was conducted from May 20, 1953, through September 30, 1954. The weather for the period was generally normal, except for precipitation. The month of May 1954, showed the only significant excess, with only two other months showing any excess. The balance of the period was so dry that the total deficiency was 17.58 inches. An average of the highest daily humidity readings which normally occur at or near sunrise showed an increase of about 3 per cent above normal. The lowest daily humidity readings usually occurring in the middle or late afternoons showed an average of about 6 per cent below normal. Temperatures for the period averaged nearly normal with the days slightly warmer and the nights slightly cooler. Wind velocities were only slightly greater than usual with no significant variation from normal.

**Table I. Propagation Test Data**

| | | | |
|---|---|---|---|
| Circuit frequency, mc | 6,730 | 1,965 | 955.5 |
| Equipment | Philco *CLR-6* | RCA *CW-20A* | RCA *CW-5A* |
| Transmitter location | Latex | Latex | Latex |
| Transmitter power output, watts (dbw) | 1 (0) | 3 (+5) | 2 (+3) |
| Receiver location | Shreveport | Shreveport | Shreveport |
| Paraboloidal antenna size | 6 feet | 6 feet | 4 feet |
| Passive reflector size | 6 × 8 feet | | |
| Nominal antenna gains, two terminals, db | 79.0 | 59.4 | 39.6 |
| System loss for free-space transmission, db | 66.3 | 77.0 | 90.8 |
| Over-all median loss, db | 80.6 | 92.0 | 105.1 |
| Assumed obstruction loss, db | 14.3 | 15.0 | 14.3 |

Fig. 3 shows the antenna installation at the Shreveport terminal. The paraboloid on the right side of the tower's cross member was illuminated by the 1,965-mc horizontally polarized dipole antenna. The paraboloid on the left was illuminated by the 955.5-mc vertically polarized dipole. The paraboloid to the left of the tower near ground level was illuminated by the 6,730-mc horizontally polarized horn-type antenna. Energy was beamed from this paraboloa to the passive reflector at the top of the mast. The paraboloid near ground level in front of the tower and the passive reflector beneath the tower platform were part of the diversity tests not reported at this time. It is interesting to note that no significant loss differences were measured between horizontal and vertical polarization checks of the 955.5-mc, 1,965-mc, and 6,730-mc circuits. Antenna gains and circuit losses are a part of Table I. Fig. 4 is a view of the radio equipment installation at the Shreveport terminal. From left to right may be seen the 6,730-mc, 1,965-mc, and 955.5-mc rf equipment. The Latex antenna and equipment installations were similar to those at Shreveport.

No description of the radio equipment used in the test will be made, because it is of standard manufacture. It will suffice to say that, because modulation was not used and band-width was not a consideration, the RCA equipment was adjusted where possible to increase its recording range. Modifications made to the Philco equipment did not increase the recording range over that obtainable from production equipment. Suitable arrangements were made for attaching signal recording instruments to the receiver for each test frequency.

## TECHNICAL METHODS

The received signal level of each circuit was recorded continuously for the test period. The following information for each 15-minute period was transcribed

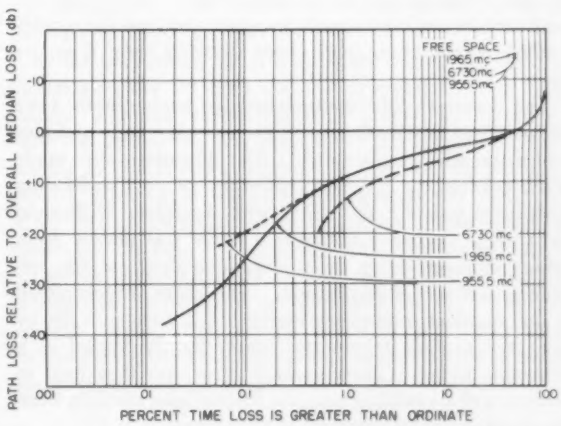


Fig. 5. The 955.5-, 1,965-, and 6,730-mc loss distribution, May 20, 1953, through September 30, 1954.

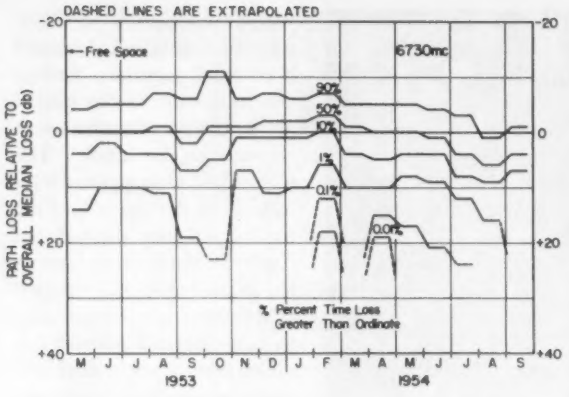


Fig. 6. The 6,730-mc seasonal probability, May 20, 1953, through September 30, 1954.

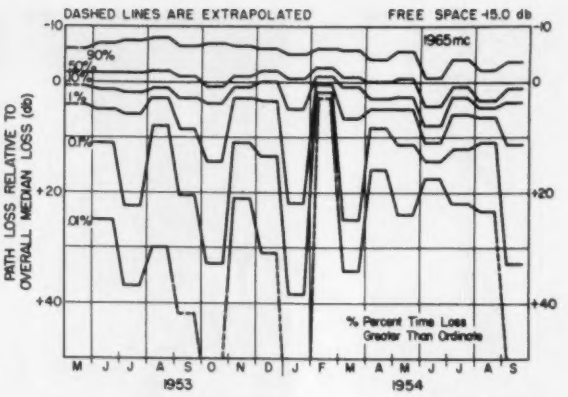


Fig. 7. The 1,965-mc seasonal probability, May 20, 1953, through September, 30, 1954.

manually from each circuit's daily chart to its daily data sheet:

1. Average loss value in db.
2. Minimum loss value in db.
3. Maximum loss value in db.
4. Number of times loss was greater than 20 db above reference value.
5. Duration of time loss was greater than 20 db above reference value, in minutes.
6. Number of times loss was greater than 30 db above reference value.
7. Duration of time loss was greater than 30 db above reference value, in minutes.
8. Number of times loss was greater than 40 db above reference value.
9. Duration of time loss was greater than 40 db above reference value, in minutes.
10. Equipment condition (one of seven symbols to denote equipment normal, under maintenance, etc.).

From the data sheets, the information was punched on International Business Machines (IBM) cards, one card for each 15-minute period for each circuit. IBM machines were used for sorting and tabulating the data but the mathematical computations and curve drawing were done by hand.

The receivers and transmitters for each circuit were calibrated as nearly as possible on a weekly basis and also before and after maintenance. All calibrations were made in db referred to 1 watt. Accuracy of the calibrating equipment was ±2 db. To provide a receiver calibration for a given period, a calibration curve was plotted from values averaged from the calibrations made at the beginning and end of that period. This curve was corrected to the standard transmitter output of 1 watt or 0 db by using the average transmitter power for the period as a correction factor. The corrected curve was then used to prepare a chart reading card for transcribing the data from the charts to the data sheets.

The speed of the recording paper was chosen as 3 inches per hour as a practical maximum. For any particular

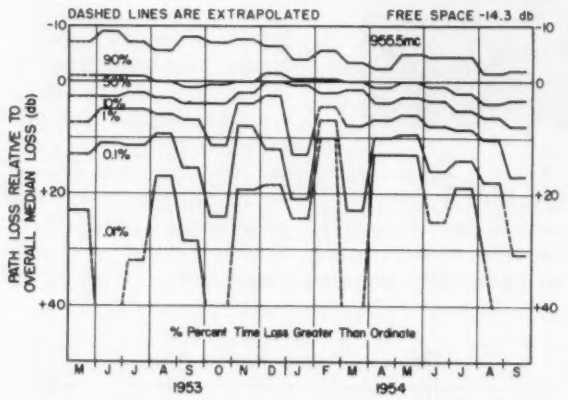


Fig. 8. The 955.5-mc seasonal probability, May 20, 1953, through September 30, 1954.

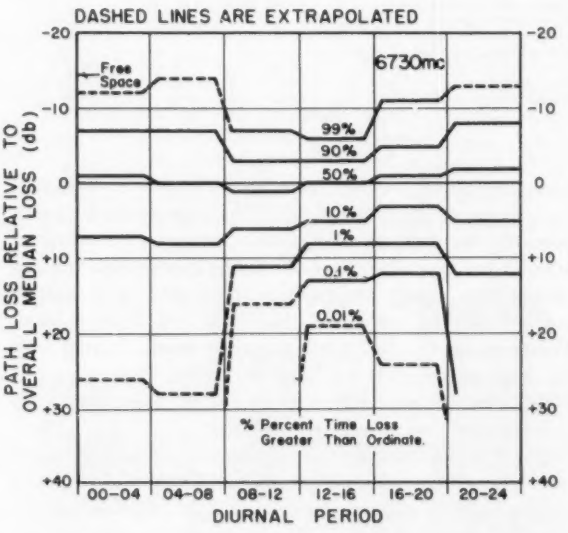


Fig. 9. The 6,730-mc diurnal probability, May 20, 1953, through September 30, 1954.

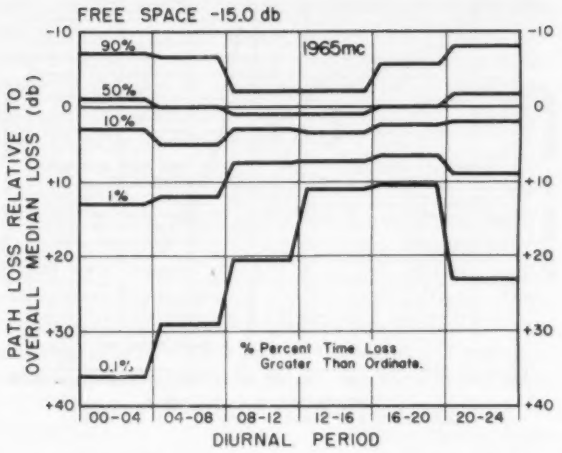


Fig. 10. The 1,965-mc diurnal probability, May 20, 1953, through September 30, 1954

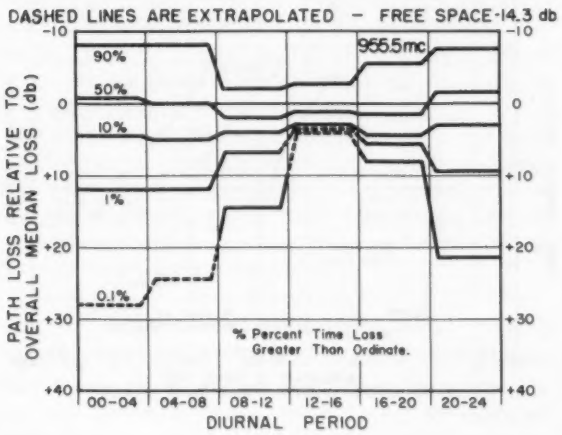


Fig. 11. The 955.5-mc diurnal probability, May 20, 1953, through September 30, 1954.

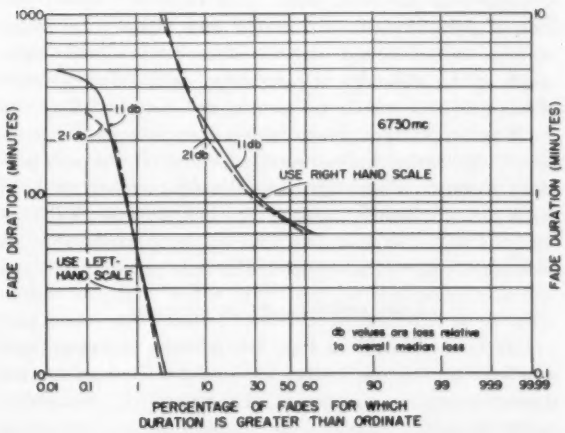


Fig. 12. The 6,730-mc fade duration distribution, December 1, 1953, through September 30, 1954.

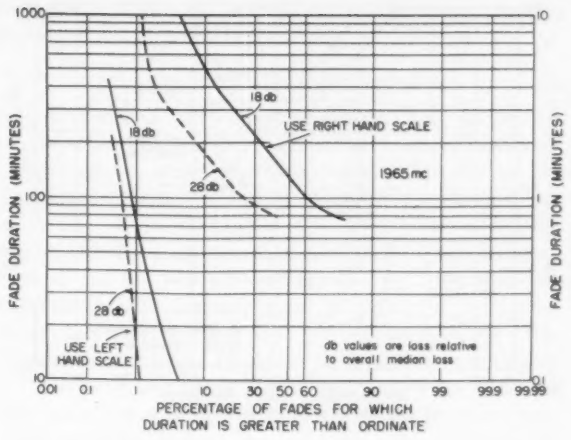


Fig. 13. The 1,965-mc fade duration distribution, May 20, 1953, through September 30, 1954.

chart speed a certain minimum fade duration can be defined due to the finite width of the pen's trace. For this chart speed a line in a downward direction followed by a return in an upward direction, 1 minute later, are barely separable from each other. For this reason and because fades of shorter than 1 minute duration were expected to contribute very little to the total outage time, all fades of 1 minute or shorter were tabulated as 1-minute fades. It was proved later that this assumption had only a very small effect upon the over-all statistics. For example, this assumption would be expected to have the greatest effect on the statistics of the 6,730-mc circuit, inasmuch as these have the shortest median fade lengths. (See Figs. 12, 13, and 14 presented later in the report. From Fig. 15 it can be seen that only 15 per cent of the total outage time was contributed by fades of 1 minute or less duration at the +21-db level. Thus, if this total time were in error by a factor of 2, it would only change the total outage time for the +21-db point on the over-all distribution curve by 7.5 per cent.) Consulting Fig. 5, this equivalent inaccuracy of signal level would make this data pessimistic by about 1 db. Similar analyses have proved none of the rest of the data to be in question by more than this 1 db.

At the start of the test it was felt that the major item of importance was the time the loss increased to fairly high values. For this reason, actual integration of the outage time was set up only for losses of 20, 30, and 40 db, with respect to the selected reference losses. As the test progressed, however, it was felt that following the variations of the median value and other values near it also would be necessary. It then was reasoned that, because the signal variations when the signal is near the median value are usually slow, it would be acceptable to use the 15-minute average signal. Thus, as an example, the outage time for the 4-db point used was the sum of the number of cards whose average loss was greater than 4 db × 15 minutes.

## DEFINITION OF TERMS

MEDIAN LOSS is that loss between transmitter output and receiver input, such that 50 per cent of the time the

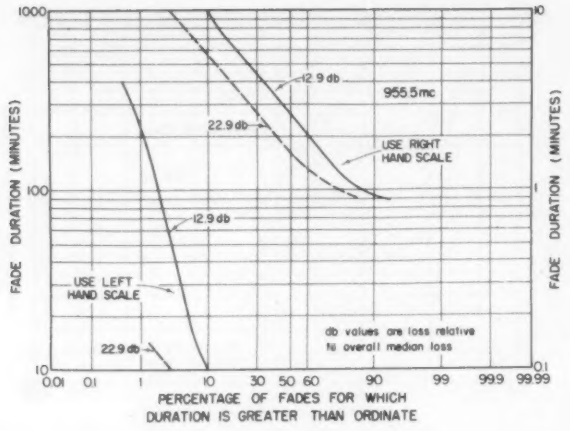


Fig. 14. The 955.5-mc fade duration distribution, May 20, 1953, through September 30, 1954.

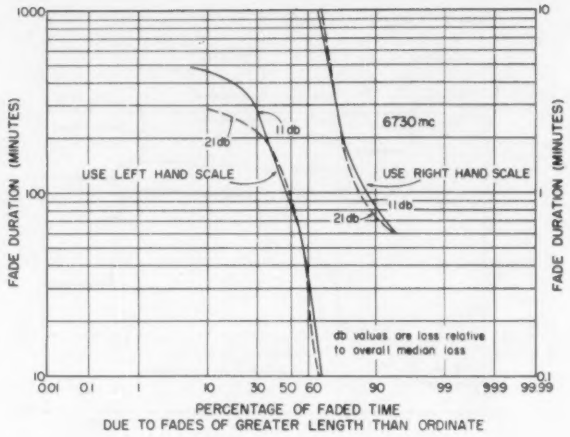


Fig. 15. The 6,730-mc faded time distribution, December 1, 1953, through September 30, 1954.

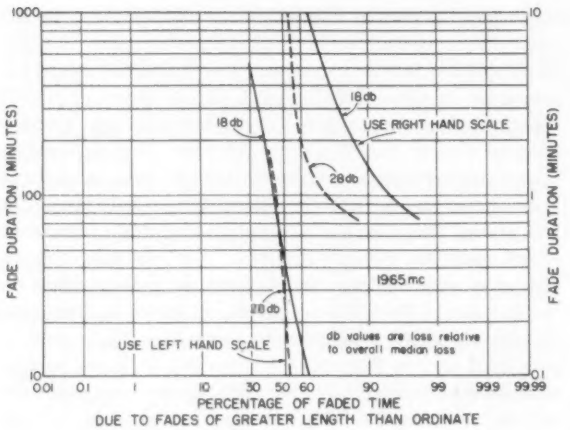


Fig. 16. The 1,965-mc faded time distribution, May 20, 1953, through September 30, 1954.

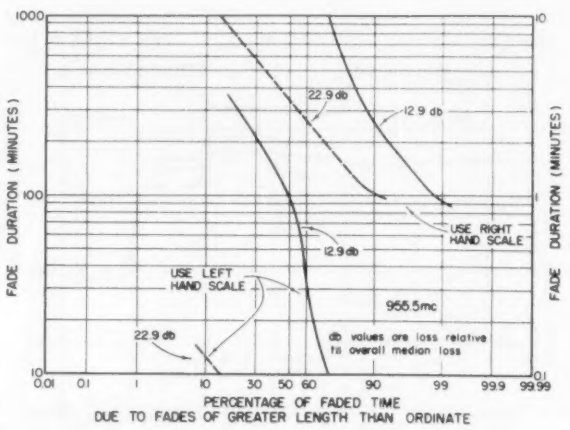


Fig. 17. The 955.5-mc faded time distribution, May 20, 1953, through September 30, 1954.

observed loss was less and 50 per cent of the time the loss was greater. In the case of over-all median loss, this definition applies to data for the entire test.

System loss for free-space transmission is the loss that would be measured between transmitter output and receiver input, if the path were operated in free space without obstructions between the antennas. This loss was computed by the equipment manufacturers using transmission line losses measured at the test site and specification gains of the antenna systems.

Assumed obstruction loss is the difference between over-all median loss and system loss for free-space transmission and represents the loss nominally attributed to the obstructions existing in the path.

## DATA

THE PRIMARY INFORMATION desired from the test was the loss distributions of the three frequencies involved, operated over the same path. In setting up the test, consideration was given to providing other data such as seasonal and diurnal variations, fade duration and faded time distributions, rate-of-fading, and weather correlations. Inasmuch as the difficulty of correlating fading and weather effects was well known, no specific and detailed effort was made in the primary phase of the test to make such correlations. A weather bureau station located on the path provided a source of weather data already punched on IBM cards on an hourly basis (Weather Bureau *WBAN-1* cards). With the test data also on IBM cards, this aspect of the test will be completed as time permits.

## LOSS DISTRIBUTION CURVES

THE CURVE shown in Fig. 5 is perhaps of the greatest significance. In this curve, the loss distributions for the three frequencies are shown. In general, it shows that as the frequency increases, the amount of time the loss is greater than a selected value increases. It must be cautioned, however, that data from this figure should not be

used alone to judge the relative quality of the different frequencies, as regards their use in microwave relay systems or their use in different geographical areas. Many other items must be considered such as antenna gain, transmission line or wave guide loss, rf output availability, and attainable receiver noise figures.

## SEASONAL PROBABILITY CURVES

In the early phases of the test it was hoped that the seasonal variations noted (Figs. 6, 7, and 8) could be correlated with seasonal changes in $K$, the effective earth's radius, since $K$ does vary on a rather periodic basis. Computations of the expected variation in signal were made, assuming grazing smooth sphere diffraction. These computations predicted that the greater losses would be present in February and the least in August. The calculated difference between the February and August median losses was 1.0 db for the 955.5-mc circuit, 1.4 db for the 1,965-mc circuit and 2.3 db for the 6,730-mc circuit. It can be seen from inspecting the data that seasonal effects of a random nature are present to such a degree that, even if the calculated effect were present, it would take many years of data to enable its extraction from the random data. For example, both the summer of 1953 and 1954 were covered by this test, but the mean signals of the summers were quite different, as shown in the median losses.

It can be noted, however, that the variation in median loss from one month to the next increases as the frequency increases. This is in accordance with theoretical expectations that a given change in path obstruction height will cause an increasing change in the value of the received signal as the frequency becomes higher.

## DIURNAL PROBABILITY CURVES

In Figs. 9, 10, and 11, loss distributions collected into 4-hour diurnal blocks are presented. From these it can be seen that the most favorable part of the day for minimum faded time is in the afternoon; also, it can be seen that the most unfavorable time is in the 4-hour interval between midnight and 4 a.m. Presumably the afternoon was most favorable, because on an average day the sun has been warming the earth for some time causing vertical turbulence, which does not support stratification.

An additional observation is that the median loss on all circuits was found to be lowest near midnight. The probable explanation of this is as follows: On a typical night, the evening starts with the ground relatively warm from the sun's radiation. As night falls, the ground radiates its heat energy into space, becoming cooler; however, the higher atmosphere does not do this. Therefore, a layer of air in immediate contact with the ground becomes cooler than the air above it and, thus, has a dielectric constant higher than that of the air above by a definite amount. This causes the effective radius of the earth $K$ to become larger and, in a grazing path such as this, causes the signal levels to rise; this effect was noticed many evenings.

Two informative types of presentation of the observed fades which occurred during the test are the fade duration distribution curves, Figs. 12, 13, and 14, and the faded time distribution curves, Figs. 15, 16, and 17. It should be mentioned that in Figs. 12 and 15 the period of time covered is not the entire test period.

## SUBJECTIVE OBSERVATIONS

One important subjective observation made during the course of this test was that it takes a great deal of information to describe accurately the statistics of even one specific propagation path. This was illustrated by several occurrences. First, the summer of 1953 was observed to have rather different characteristics as regards median loss and type of fading than the summer of 1954. Second, the substandard fades were infrequent but because of their great length had a sizable effect upon the over-all statistics. For example, in the entire 16 months of the test there were only six fades of 30 minutes or longer duration for the 1,965-mc channel at the −18-db level. These fades, however, contributed 52 per cent of the total faded time at that level.

## CONCLUSIONS

On the basis of the data taken during this test, the loss is greater than a given value relative to median loss for a larger percentage of time as frequency increases. In general, fades become more frequent but shorter in duration as the frequency increases. It can be seen that grazing paths of the type tested here suffer a sizable obstruction loss—in this case, 14 db to 15 db. The 1,965-mc data presented has been compared for a 4-month period with other propagation data taken on 2,000 mc on paths of similar length in the same locale, but with adequate clearance to insure their median signals being near the free space value. This comparison revealed that the grazing path was 30 db or more below free-space value, three times longer than the clear path, and 40 db or more, nearly five times longer. Caution should be used in considering the actual value of the reliability advantage. A comparison of the circuit outage time for the two hops showed the time advantage on the clear path to be approximately 3 hours for the 4-month period. This advantage was purchased for nearly three times the antenna cost. Land required for guying would cost about four times as much and the tower proper twice as much.

The importance of good propagation reliability for systems using telemetering, remote control, and supervisory functions is apparent from an examination of the diurnal curves, which show that periods of maximum loss occur during the periods of greatest need for control functions. It should be emphasized again that, in addition to the important factor of propagation reliability, other factors such as antenna gain, transmission line loss, and economic aspects must be considered in the design.

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2. Selective Fading of Microwaves, **A. B. Crawford, W. F. Jakes.** *Bell System Technical Journal*, New York, N. Y., vol. 31, January 1952, pp. 68–90.

3. Results of Microwave Propagation Tests on a 40-Mile Overland Path, **A. L. Durkee.** *Proceedings*, Institute of Radio Engineers, New York, N. Y., vol. 36, February 1948, pp. 197–205.

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# Eastlake Power Plant Reappraised

C. F. PAULUS
MEMBER AIEE

PROGRESS in the design of steam-electric generating stations is not an even, forward movement. New generators are installed in existing plants more frequently than in plants at new locations. The effect of this is that possibly 25 years or so can pass before the engineers have an opportunity to design a new plant, free of those restrictions which frequently make it impossible to utilize fully the new equipment which has been made available, as well as the new techniques which have been developed.

It happens then that the design of a new plant becomes the occasion for the introduction of innumerable new ideas that have accumulated. Within the last 10-year period an unusually large number of new plants have been designed. The present time seems to be a particularly appropriate time to take a second look at some of these plants and to determine whether or not the engineers overdesigned them. A session at the 1956 AIEE Summer and Pacific General Meeting was devoted to this subject. Each of the several papers described a particular plant and then re-evaluated the over-all design philosophy from an electrical viewpoint and described in greater detail those features which are being modified in present designs. These plants differ widely and yet they have one thing in common: each plant is designed to generate power at the lowest cost for the particular location in which it is built.

The first unit at the Eastlake station of the Cleveland (Ohio) Electric Illuminating Company was placed in service in the latter part of 1953. Two units similar to the first have been added to this plant and another two new units have been engineered since that date. The modification in design being introduced with these units are a concrete measure of the changes which have been found desirable and constitute a reappraisal of the plant.

The one-line diagram of main circuits of Eastlake units *1*, *2*, and *3* brings out the simplicity and uniformity of the electric circuits (Fig. 1). This simple arrangement assured low first cost and low maintenance, plus reliability.

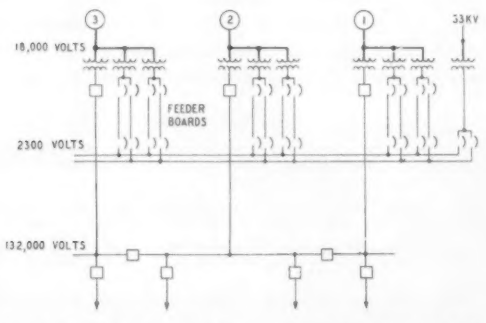


Fig. 1. One-line diagram of main circuits of Eastlake units 1, 2, and 3.

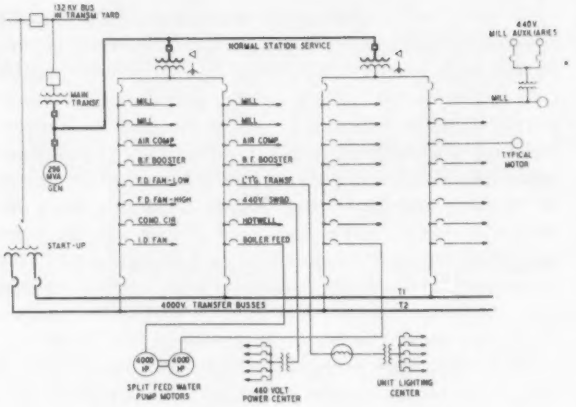


Fig. 2. One-line diagram of auxiliary circuits of new unit at Avon.

This basic layout is being repeated for two new units rated 240 mw and 250 mw. Fig. 2 shows the auxiliary circuits in which some modifications have been made. The practice of installing the largest available tandem-compound units is continued. As one of these units is in the supercritical range the supply to the feedwater pump motor has created a new problem. Motor loads as large as 8,000 hp can be supplied at 4,000 volts using standard 250-mva metalclad switchgear, if split busses and tandem motors are used as shown in Fig. 2.

Motor-generator type exciters are being used with no spares. The use of conductor-cooled generators on both these machines has kept their dimensions below that of some lower rated machines in service. They should be less subject to field failure which currently appears to be one of the biggest problems. Other practices proved successful are the reduction of conduit, elimination of embedded conduit and ground wires, welding of all ground connections and the use of iron earthing, use of armored cables, and unitization of all electric circuits.

The electrical design of Eastlake represents a sharp simplification compared to earlier layouts. The cost reductions are substantial. The operating record shows that the plant was not overdesigned.

The design practices, which resulted in an enclosed plant with a building volume of 17.5 cubic feet and a cost of $122 per kw of gross capability for the initial three units with a net heat rate for 1955 of 9,336 Btu per kwhr, deserve being retained. Wherever possible, future units will be simplified even further.

Digest of paper 56-776, "Eastlake Reappraised," recommended by the AIEE Committee on Power Generation and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, San Francisco, Calif., June 25-29, 1956. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1956.

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# Digital Computer Solution of Stability Problems

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WITH THE EXPANSION and increase in complexity of power systems throughout the country, a more accurate and less time-consuming means of determining the transient stability characteristics of power networks has been required. The solution of power system transient stability problems has, in the immediate past, been accomplished primarily by the use of analogue computer such as the a-c network analyzers. In view of the recent development and availability of effective digital computing devices, a general trend in engineering is toward the use of digital computers in an increasing number of applications. Of the many problems originating in the analysis and operation of power systems, one which lends itself especially to solution by digital computers is that of system transient stability. In applying high-speed computers to familiar problems, it is desirable to consider other available numerical methods rather than simply to mechanize techniques which have been used in the past for hand calculation.

Methods previously developed have used either network analyzers or digital computation to determine the power output of the system sources. In the swing equation

$$M_n \frac{d^2\delta_n}{dt^2} = P_{in_n} - P_{out_n} = f(\delta_n) \qquad (1)$$

the solution of the nonlinear second order differential equation has been accomplished by relatively inaccurate first approximation or single correction methods. This has been necessary for network analyzer operation because of the time involved in the hand calculations and the attendant checking. In a digital computer solution, however, more accurate methods may be evaluated.

Kutta and Runge have offered what seems to be a commendable method for approximating the solution of the second-order differential equation 1. The properties of this solution are that it is self-starting, each time increment calculation is completely self-contained, and it has accuracies which are available with few other methods. Whereas the error per time increment of the traditional step-by-step solution is of the order of $\Delta t^2$ and of the single correction methods of the order of $\Delta t^3$, the error by the Kutta–Runge method is of the order of $\Delta t^4$.

Using the Kutta–Runge fourth approximation method of solution, the operations per time increment are between four and five times those involved in solution of the problem by means of the traditional step-by-step solution. The increased accuracy of the Kutta–Runge method is such that it allows a time increment five times greater than that usually used with the traditional methods while resulting in considerably greater accuracy. This means that per unit computer time, the Kutta–Runge method can be used to advantage.

Fig. 1 shows comparative results of swing curves calculated for a sample single-machine and infinite bus problem which was set up to be barely stable as determined by the equal-area criterion. It can be observed that the Kutta–Runge solution using a time increment of 0.10 second shows the system to be more critical than the traditional step-by-step solution using time increments of either 0.10 or 0.02 second. Other test studies have been run on larger systems. Although the results obtained by the two different methods vary to different degrees, the Kutta–Runge method consistently yields more accurate results.

The accuracy and self-contained time increment properties of the Kutta–Runge solution particularly suit it to use in studies of critical clearing time. At any time during the calculation, the time increment of the next incremental calculation may be changed without variation of computational procedure.

The time requirements of a digital computer transient stability study will, of course, vary with the magnitude of the problem and the size of the computer used. Using a three-machine problem as a basis of comparison; about 15 minutes per time increment were required for operation upon the IBM (International Business Machines Corporation) *604* or *CPC*, and approximately 3 minutes per time increment on the Datatron or IBM *650*. Changes of time increment while the solution is under way do not affect the total operating time appreciably. The time requirement for a digital solution of the transient stability problem varies approximately with the square of the number of equivalent machines considered.

Digest of paper 56-923, "The Solution of Power System Stability Problems by Means of Digital Computers," recommended by the AIEE Committee on System Engineering and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Fall General Meeting, Chicago, Ill., October 1–5, 1956. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1956.

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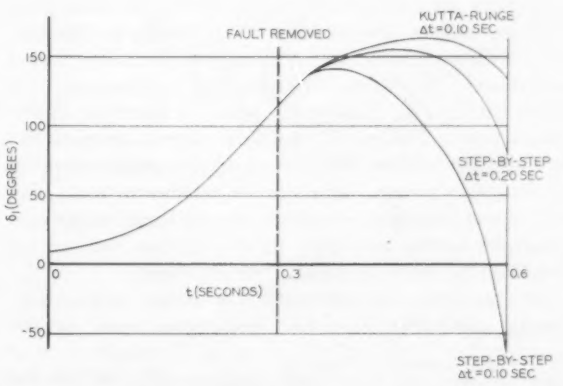


**Fig. 1. Graphical comparison of results of step-by-step and Kutta–Runge solutions of the sample single-machine problem.**

# A Unified Approach to the Teaching of Electromechanical Energy Conversion

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A. KUSKO
MEMBER AIEE

**This approach presents a consistent treatment of electromechanical-energy conversion using the theory of circuits and fields in relative motion. The approach is an attempt to produce an acceptable solution to present-day electrical engineering curricula.**

A GENERALIZED BUT UNIFIED APPROACH to the teaching of electric machines, that is currently being incorporated in the new curriculum for electrical engineering at the Massachusetts Institute of Technology,[1] Cambridge, Mass., is presented. Attempts have been made in the past to incorporate a generalized treatment of machinery in engineering curricula, but either the students' technical background was weak or the subject failed to maintain continuity when attempting to cover both the general concepts, as well as the details of machine construction and operation. This approach is an attempt to produce an acceptable solution for present-day electrical engineering curricula.

## BACKGROUND

INASMUCH AS THIS UNIFIED APPROACH is highly generalized, it is well to show how the material is placed relative to background and accompanying subjects offered to all electrical majors in the curriculum. As described in a recent paper,[2] this approach to electric machinery is incorporated in the last of the three required undergraduate subjects, which comprise the energy-conversion stem. Two of the subjects in this sequence are taught during the third year, and the subject described herein is taught in the first term of the fourth year. These three subjects are entitled as follows: (1) Fields, Materials, and Components; (2) Electrical Energy Converters; and (3) Electrical Power Modulators. The first of the three subjects develops the relationships between field concepts and circuit quantities for stationary systems and systems in relative motion. The second and third of these subjects develop these background principles further and apply them to devices and systems involving the conversion and control of energy.

The students who undertake this unified approach to electric machinery have had background work[2] in the following areas: (1) circuit theory, including a sound grounding in the concepts of complex frequency; (2) field theory, including Maxwell's equations, quasi-statics, and elementary relativity; 3) the microscopic (molecular) theory of dielectric and magnetic materials; (4) the use of materials and fields for realizing the functions of the storage, transfer, and conversion of energy; (5) electronics—treating circuits, components, and systems; and (6) a treatment of incremental-motion electromechanical energy conversion devices, including the use of generalized co-ordinates and Lagrange's equations.

## PHILOSOPHY

THE OBJECTIVE of this treatment of electric machinery is not to train specialists in the details of electric machine design, but to present a consistent treatment of electromechanical energy conversion using the theory of circuits and fields in relative motion. In this way, a sound scientific structure can be built, based upon the students' background of field and circuit theory. Also, the results of the analysis of a highly idealized geometry of materials can be applied to specific machines, showing that these special cases lead to the results normally obtainable from a more specialized and restricted approach.

The scientific concepts used to study electromechanical energy converters are not reduced to a specialized and restricted form, valid only for those conditions found in present-day electromechanical devices. Instead, the scientific principles are formulated in a more general form than is necessary for the specific problem. In this way, the concepts developed are applicable to other than electromechanics and, further, the approximations made in the conventional study of electromechanics are made evident. For example, the relationship between the low-velocity electromechanical devices and the high-velocity particle-acceleration devices is established by using special relativity to develop the energy-conversion principles. Similarly, the use of energy functions, particularly the Lagrangian, to obtain the equations of motion in electromechanics establishes the broad interrelations between various energy-conversion systems that are encompassed in the concepts of analytical dynamics and thermodynamics.

With this broad general background, each student can acquire the detailed information that he requires for his professional work in any area of specific devices; he is also prepared to keep pace with future scientific developments. For example, he may wish to acquire detailed information on acoustic transducers, servo machinery, or synchronous

A special article recommended by the AIEE Committee on Education.

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machines, or he may wish to study more advanced energy-conversion principles associated with high-velocity particles. This task should be straightforward, once the student understands the underlying field and circuit behavior of the whole class of electromechanical energy conversion devices and recognizes the interrelationships between electromechanical and other energy-conversion systems.

The laboratory in this approach serves the function of giving the students a physical understanding of the analytical concepts developed in the lecture room and shows how specific machines can be derived from selected generalized machines. These specific machines need not be one of the half-dozen dominant machine types, but can result from many possible combinations of windings, commutators, and movable brushes.

## OUTLINE OF APPROACH

THE PRESENT APPROACH to energy conversion recognizes two major functions of energy converters. These are: (1) energy conversion—the interaction of physical systems that result in a change in energy from one form to another; and (2) power modulation—the dynamics of energy converters, formulated as terminal behavior for system operation. The steps in the unified approach to electric machinery that will be covered in this article are outlined according to the section in which they are discussed.

*Physical Structure.* Selection is made of physical structures that lead to equations of motion which describe most electric machines. In this article, the structure chosen is a smooth cylindrical rotor and stator of infinitely permeable material (other physical structures are also considered in the course: Electrical Power Modulators). Conducting sheets with infinite conductivity in the $\phi$ or tangential direction are assumed on both surfaces facing the air gap. Two-phase current sheets are established on both sides of the air gap, and current densities in these current sheets vary sinusoidally with peripheral angle. Each current sheet is excited at a pair of terminals attached to the coordinate system of the current sheet.

*Field Solution.* Solution for the $\bar{E}$ and $\bar{H}$ field distribution produced by the current sheets in the gap space is found using the concepts of special relativity and quasi-statics. The field solution is expanded in a power series in frequency and all terms above the first order in frequency are neglected. This field solution expressed as a power series in frequency can be found from the static fields by a repeated application of Maxwell's equations and the boundary condition for moving material bodies. The approximation in the frequency domain can be carried over into the time domain by Laplace transform concepts, provided the transients considered are sufficiently long so that they do not invalidate the frequency-domain approximation. In electromechanics, where millisecond response is considered fast, the quasi-static approximation is valid.

*Power Flow.* Electric- and magnetic-field solutions are investigated using Poynting's Theorem extended to systems in relative motion to determine the pattern of power flow in the air gap. In this way, the necessary conditions for energy conversion are established.

*Inductance Matrix.* Field quantities are expressed in terms of the excitation at the terminals. Then the stored energy in the static fields is used to define an inductance matrix, thereby establishing a circuit representation of the physical structure as seen from its terminals.

*Converters.* The complete set of differential equations is found by one of several methods, among which the application of the Euler-Lagrange equations to the Lagrangian of the system is the most general way to find the desired set of equations of motion.

*Constraints.* The equations of motion of the idealized machine are subjected to transformations or changes of variables and to specific constraints as a means for obtaining the equations of specific machines. These transformations are shown to reduce the number of independent variables that produce torque, or to eliminate the angular or time dependence of the inductances. One set of these transformations also is shown to stem physically from the action of a commutator. These equations of motion are the system differential equations and are applicable to both steady-state and dynamic problems.

*Control Applications.* General equations of motion for specific machines are reduced to approximate forms and represented schematically for control application and system studies.

*Laboratory.* Newly developed laboratory equipment is described that illustrates the transformation theory of machines, as well as the operation of specific machine types.

## PHYSICAL STRUCTURE

SEVERAL IDEALIZED PHYSICAL STRUCTURES are used to develop the unified approach to electric machinery. The physical structure chosen as illustrative for this article is shown in Fig. 1; it consists of two concentric magnetic

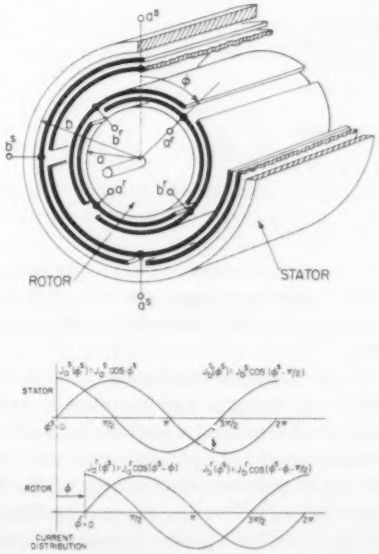


Fig. 1. Idealized energy converter with 2-phase sinusoidal current sheets on rotor and stator.

cylinders that may rotate with respect to one another. Located along the surfaces of the magnetic structures and facing the air gap are current sheets in which the current densities are assumed sinusoidally distributed with peripheral angles in such a way as to make up a 2-pole 2-phase system on each side of the air gap. This is obviously an idealization of the conductor current distribution in a 2-phase distributed winding system. This equivalent conducting sheet has zero conductivity in the $\phi$ direction and infinite conductivity in the $z$ direction. The magnetic materials are assumed to have infinite permeability so that the magnetic-field energy is confined to the air-gap space.

## FIELD SOLUTION

THE ELECTRIC AND MAGNETIC FIELDS in the physical structure of Fig. 1, that result from exciting the stator and rotor current sheets, can be used to study both the static and dynamic energy-conversion properties of this machine. These fields can be evaluated using Maxwell's field equations and the boundary conditions imposed by the physical structure. The boundary conditions for systems in which material bodies move relative to one another lead to difficulties, which can only be resolved by the use of special relativity in one form or another. The electromagnetic-field theory for moving material bodies has been developed by Minkowski,[3] and using his work Sommerfield[4] shows that the constituent relations for moving material bodies are

$$\left.\begin{aligned} &\bar{D}+\frac{1}{c^2}\bar{v}\times\bar{H}=\epsilon(\bar{E}+\bar{v}\times\bar{B})\\ &\bar{B}-\frac{1}{c^2}\bar{v}\times\bar{E}=\mu(\bar{H}-\bar{v}\times\bar{D})\\ &\bar{J}-\rho\bar{v}=\frac{\sigma}{\sqrt{1-\beta^2}}\left\{(\bar{E}+\bar{v}\times\bar{D})-\frac{\bar{v}}{c}\left[\frac{\bar{v}}{c}\cdot(\bar{E}+\bar{v}\times\bar{B})\right]\right\}\end{aligned}\right\} \tag{1}$$

By limiting our solution to velocities small compared to the velocity of light (i.e., $v/c<<1$), the following boundary conditions for the field in the physical structure of Fig. 1 can be written

Stator

$$\left.\begin{aligned} \bar{D}^s&=E^s\bar{E}^s\\ \bar{B}^s&=\mu^s\bar{H}^s\\ \bar{J}^s&=\sigma^s\bar{E}^s\end{aligned}\right\} \tag{2}$$

Rotor

$$\left.\begin{aligned} \bar{D}^r&=E^r(\bar{E}^s+\bar{v}\times\bar{B}^s)\\ \bar{B}^r&=\mu^r(\bar{H}^s-\bar{v}\times\bar{D}^s)\\ \bar{J}^r&=\sigma^r(\bar{E}^s+\bar{v}\times\bar{B}^s)\end{aligned}\right\} \tag{3}$$

where the superscript $s$ refers to stator quantities measured in the stator co-ordinate system and the superscript $r$ refers to rotor quantities measured in the rotor co-ordinate system.

These boundary conditions can now be used with Maxwell's equations to find the electric and magnetic fields. A particularly useful technique for finding these fields is to consider conditions of steady-state excitation and to define the space and time dependency of the fields to be of the form $\underline{\bar{A}}(t)=\underline{\bar{A}}e^{j\omega t}$. The space dependent term $\underline{\bar{A}}$ can then be expanded in a power series in frequency. Expanding the field quantities $\underline{\bar{E}}$, $\underline{\bar{H}}$, and $\underline{\bar{J}}$ in such a power series yields

$$\left.\begin{aligned} \underline{\bar{E}}&=\underline{\bar{E}}_0+\omega\underline{\bar{E}}_1+\omega^2\underline{\bar{E}}_2+\dots\\ \underline{\bar{H}}&=\underline{\bar{H}}_0+\omega\underline{\bar{H}}_1+\omega^2\underline{\bar{H}}_2+\dots\\ \underline{\bar{J}}&=\underline{\bar{J}}_0+\omega\underline{\bar{J}}_1+\omega^2\underline{\bar{J}}_2+\dots\end{aligned}\right\} \tag{4}$$

Now those field quantities substituted into Maxwell's equations expressed in terms of sinusoidal steady-state field vectors for an assumed time dependence of $e^{j\omega t}$ yield a set of nontime dependent equations of the form

$$\left.\begin{aligned} \nabla\times\underline{\bar{E}}_n&=-j\underline{\bar{B}}_{n-1}\\ \nabla\times\underline{\bar{H}}_n&=\underline{\bar{J}}_n+j\underline{\bar{D}}_{n-1}\end{aligned}\right\} \tag{5}$$

Repeated solution of those nontime dependent equations, starting with the zero order fields $n=0$, will generate the complete steady-state field solution. For the physical structure of Fig. 1, it can be shown that neglecting fields which are proportional to $v/c^2$ and $\omega/c^2$ will lead to the existence of only a zero-order magnetic field and a zero- and first-order electric field. These fields can be designated as quasi-static fields. For the physical structure of Fig. 1, the quasi-static fields found using equations 4 and 5, and the boundary conditions of equations 2 and 3 have the following general character: (1) The magnetic field is exactly the magnetic field that would exist without rotation and is of the form of the field which nontime varying currents would produce. This result is a direct consequence of our being able to neglect displacement currents because their effects are negligible at the range of frequencies and velocities of interest in most electric machines. (2) The electric field consists of three basic fields: resistive induced fields (proportional to $1/\sigma^s$ and $1/\sigma^r$), speed induced fields (proportional to $\phi$), and time derivative induced fields or transformer fields (proportional to $j\omega$ or $\partial B/\partial t$).

## POWER FLOW AND ENERGY CONVERSION

THE TOTAL electric and magnetic fields can be used to determine the total power flow and, hence, the energy conversion terms. The power flow through any region can be found from Poynting's vector $\bar{S}=\bar{E}\times\bar{H}$, where $\bar{S}$ is the instantaneous power flow per unit area across a surface. If one integrates $\bar{E}\times\bar{H}$ over a closed surface $\bar{A}$ that is of length $l$ and encloses the air gap, plus the current sheets on stator and rotor, one obtains the instantaneous power flow into the machine from all electrical sources. This power flow for the physical structure of Fig. 1 can be recognized as consisting of three parts: (1) the power converted to joule heat, (2) the power flow into the magnetic field, and (3) the power converted to mechanical work. The joule heat can be easily recognized as those terms proportional to $1/\sigma^s$ and $1/\sigma^r$. The power flow into the magnetic field is more difficult to recognize, but if a surface integral of $\bar{E}\times\bar{H}$ is performed that encloses the air gap and excludes the current sheets, the power flow into the magnetic field is determined. This integral yields the interesting result that the power flow into the magnetic field consists of terms which would exist if the rotor did not rotate, plus a term proportional to speed $\phi$. The speed-dependent power flow associated with the magnetic field proves to be just equal to the power converted to

mechanical work. Hence, one half of the speed-dependent power flow goes into the magnetic field, and the other one half goes into mechanical work. Other useful and informative studies of machine operation can be investigated, using the Poynting vector.

## FORMULATION OF THE INDUCTANCE MATRIX

THE ELECTROMAGNETIC FIELDS in the idealized structure of Fig. 1 are useful for studying the energy-conversion process and for determining performance characteristics under steady-state operation. There are many problems in which the dynamic performance of the energy converter, as represented at its terminals, is needed so that its performance can be correlated with system performance. The dynamic performance can be determined much more easily using the techniques of circuit theory and analytical mechanics than by using field techniques.

To formulate the dynamic problem of an electromechanical energy converter, it is necessary to know the dependence or interaction of the electrical variables on the mechanical variables and vice versa. The field theory proves to be valuable for determining this dependence, since the fields $\bar{E}$ and $\bar{B}$ which couple the electric systems on stator and rotor are expressed as functions of the space co-ordinates of the mechanical system. The desired functional dependence of the electrical parameters $L$ and $C$ on space co-ordinates can be obtained either from the Poynting vector or by equating the stored energy in the electromagnetic field to the stored energy, as expressed in terms of the voltages, currents, and parameters.

The only significant stored energy in the machine of Fig. 1 has been shown to be the magnetic stored energy. Thus, all terms in the parameter matrix can be determined by equating the stored magnetic field energy as expressed in terms of the inductances and currents ($\Sigma_i\Sigma_j L_{ij} i_i i_j$) with the stored energy in terms of the field quantities

$$\left[1/2\int_{\text{volume}} BH \quad d\,(\text{volume})\right]$$

A term-by-term matching of coefficients leads to the values of the inductance matrix including any positional dependence. The resulting matrix for Fig. 1 is

$$\mathfrak{L}=\begin{array}{|c|c|c|c|}\hline L^s & & L^{sr}\cos\phi & -L^{sr}\sin\phi \\ \hline & L^s & L^{sr}\sin\phi & L^{sr}\cos\phi \\ \hline L^{sr}\cos\phi & L^{sr}\sin\phi & L^r & \\ \hline -L^{sr}\sin\phi & L^{sr}\cos\phi & & L^r \\ \hline\end{array} \tag{6}$$

In this matrix, the term $L^{sr}$ is the peak amplitude of the mutual inductance which varies as a function of angle between any two stator and rotor windings, and the inductance $L^s$ and $L^r$ are the self inductance of the stator and rotor coils, respectively.

## GENERALIZED ELECTROMECHANICAL CONVERTER

THE DYNAMIC EQUATIONS of motion of the electromechanical-energy converter describes the device for both mechanical and electrical transients. The circuit parameters obtained from quasi-static fields were shown to be valid for electric transients, providing the maximum frequency in the transient did not violate quasi-static concepts and the maximum acceleration did not invalidate special relativity. In machines, neither of these conditions are normally violated.

The five differential equations for the idealized machine can be determined in several ways from the inductance matrix and the other parameters of the device. Four of the differential equations will have the phase voltages as driving forces; the fifth equation will have the applied external torque as the driving force. In one approach, the first four equations can be written from Kirchoff's Law and the fifth equation from mechanics with the electromechanical torque determined from the $f=Bli$ relationship. In the second method, the first four equations are written in the same way, but the electromechanical torque is determined from conservation of energy after applying a virtual displacement to the rotor. In the third method, the Lagrangian of the system is determined using the electric currents as generalized velocities and the mechanical angle $\phi$ as a generalized co-ordinate. The application of the Euler-Lagrange Equation to the Lagrangian of the system for each of the generalized co-ordinates and velocities yields the five differential equations. Using any of these methods the resulting equations are

*Electrical Equations:*

$$\begin{array}{|c|}\hline v_a^s \\ \hline v_b^s \\ \hline v_a^r \\ \hline v_b^r \\ \hline\end{array} = \begin{array}{|c|c|c|c|}\hline R^s+pL^s & & pL^{sr}\cos\phi & -pL^{sr}\sin\phi \\ \hline & R^s+pL^s & pL^{sr}\sin\phi & pL^{sr}\cos\phi \\ \hline pL^{sr}\cos\phi & pL^{sr}\sin\phi & R^r+pL^r & \\ \hline -pL^{sr}\sin\phi & pL^{sr}\cos\phi & & R^r+pL^r \\ \hline\end{array} \begin{array}{|c|}\hline i_a^s \\ \hline i_b^s \\ \hline i_a^r \\ \hline i_b^r \\ \hline\end{array} \tag{7}$$

*Mechanical Equation*

$$T=(J\ddot{\phi}+\alpha\dot{\phi})-[(i_a^r i_b^s-i_a^s i_b^r)\cos\phi-(i_b^s i_b^r+i_a^s i_a^r)\sin\phi] \tag{8}$$

The resulting equations which describe the operation of the converter are a set of five simultaneous nonlinear differential equations. These equations were derived in terms of the actual current, voltages, and parameters, as measured on the stator and the rotor. The interesting characteristic of these equations is that they can be shown to be the basic equations of most rotating machines merely by introducing various constraints.

## SPECIFIC MACHINES BY CONSTRAINTS

TWO TYPES of constraints are of interest: the first is the physical one enforced by a commutator or by winding interconnections; the second is that produced by sources, that is the applied currents, voltages, torques, and speeds.

A transformation of particular importance in electric machines can be developed by considering how the magnetic fields, produced by a sinusoidally space-distributed current sheet attached to a moving system (the rotor), can be produced by a set of current sheets located at the surface of the rotor but stationary with respect to the stator. Referring to Fig. 2, it can be seen that one solution is obtained by locating two current sheets in space quadrature at the surface of the rotor and stationary with respect to the stator. If the rotor terminal currents $i_d^r$ and $i_q^r$ in Fig. 2, which

generate the two current sheets, are related to the rotor current $i_a^r$ as follows:

$$i_d^r = i_a^r (\cos \phi) \tag{9}$$

$$i_q^r = i_a^r (\sin \phi) \tag{10}$$

then the two current sheets at the surface of the rotor produce the same magnetic fields in the air gap as does the current sheet attached to the moving rotor. In view of this equality, it is obvious that a set of 2-phase rotor currents attached to the rotor can be translated to a set of rotor currents stationary with respect to the stator by the transformation

$$\begin{bmatrix} i_d^r \\ i_q^r \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & +\cos\phi \end{bmatrix} \begin{bmatrix} i_a^r \\ i_b^r \end{bmatrix} \tag{11}$$

Using this transformation for both currents and voltages, the equations of motion equations 7 and 8 for the energy converter of Fig. 1 assume the following form:

Electrical:

$$\begin{bmatrix} v_a^s \\ v_b^s \\ v_d^r \\ v_q^r \end{bmatrix} = \begin{bmatrix} R^s+pL^s & & L^{sr}p & \\ & R^s+pL^s & & L^{sr}p \\ L^{sr}p & L^{sr}\phi & R^r+pL^s & L^r\phi \\ -L^{sr}\phi & L^{sr}p & -L^s\phi & R^r+pL^r \end{bmatrix} \begin{bmatrix} i_a^s \\ i_b^s \\ i_d^r \\ i_q^r \end{bmatrix} \tag{12}$$

*Mechanical:*

$$T = J\ddot{\phi} + \alpha\dot{\phi} - [L^{sr}(i_b^s i_d^r - i_a^s i_q^r)] \tag{13}$$

Note that the electrical equations for constant-speed operation are a set of linear differential equations with constant coefficients.

The transformation of equation 11 has an interesting interpretation in addition to the one already given. In commutator machines, the action of the commutator can be interpreted as translating currents and voltages from the moving to the stationary system. This interpretation can be developed from Fig. 3 by assuming that the two stationary current sheets at the rotor surface are actually established by a set of conducting brushes, which inject the required current density into the rotor while the brushes remain fixed in space with respect to the stator That is, the transformed currents $i_d^r$ and $i_q^r$ in equation 11 can be interpreted as the actual brush currents at the corresponding space positions in an actual commutator machine. A resultant sinusoidally distributed current sheet that moves with the rotor is thereby produced by the two sets of brushes. To extend this concept to a commutator machine, it must be realized that a sinusoidal current sheet is but the fundamental space harmonic of the actual space distribution current. The transformation of equation 11 must be applied to all space harmonics recognizing that $\phi$ becomes $n\phi$ for the $n$th harmonic. The resulting equation when all harmonics are accounted for will be similar to equation 12 except that the $\phi$ terms will change from $L^{sr}\phi$ to $K_1L^{sr}\phi$, and $L^r\phi$ to $K_2L^r\phi$. Similarly the $pL$ terms will change to $pK_3L$, etc. Using the extension, equations 12 and 13 can be used for both commutator and noncommutator machines.

Equations 12 and 13 can now be shown to lead to the circuit equations for a d-c machine by setting $i_a^s = i_f$; $i_b^s = 0$; $i_d^r = 0$; $i_q^r = i_a$; $\psi_f = K_1L^{sr}i_f$. Resulting equations are

$$\begin{aligned} v_f &= (R_f + pL_f)i_f \\ v_a &= +\psi_f\dot{\phi} + (R_a + pL_a)i_a \\ T &= J\ddot{\phi} + \phi\psi_f i_a \end{aligned} \tag{14}$$

These equations are easily recognized as those of a d-c motor for $i_a$ positive and a d-c generator for $i_a$ negative.

Equations 12 and 13 can also be shown to lead to Park's Equations for a synchronous machine by setting $i_a^s = i_f$, and $i_b^s = 0$. The resulting equations are

$$\begin{aligned} v_f &= R_f i_f + p(L^s i_f + L^{sr} i^r) \\ v_d^r &= R^r i_d^r + p(L^{sr} i_f + L^r i_d^r) + \dot{\phi}(L^r i_q^r) \\ v_q^r &= R^r i_q^r + p(L^r i^r) - \dot{\phi}(L^{sr} i_f + L^r i_d^r) \\ T &= J\ddot{\phi} + \alpha\dot{\phi} + [L^{sr}(-i_f i_q^r)] \end{aligned}$$

These are but two examples of well-known machines obtained by applying specific constraints to the equations for the energy converter of Fig. 1. The students also derive other machines including the induction machine and repulsion machine from these equations of motion. The fact that the dynamics of many machines can be obtained from the equations of motion for the physical structure of Fig. 1 by imposing different constraints is a very valuable concept for understanding the operation of all electric machines.

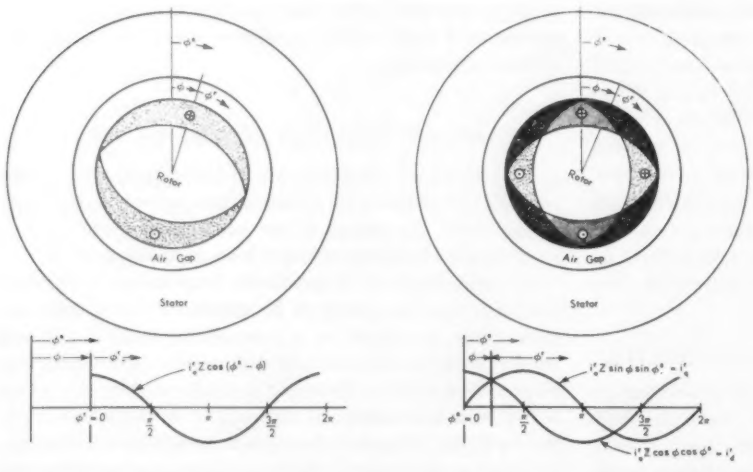


Fig. 2. Rotor current densities which produce the same air-gap fields. Rotor current density remains fixed with respect to rotor *(left)* and with respect to stator *(right)*.

## CONTROL APPLICATIONS

THE EQUATIONS developed in the previous sections are too complicated for use in most control system studies. In many cases, these equations can be simplified by consider-

ing special constraints used to obtain specific control properties or neglecting all terms that are small for a given control operation. Equivalent circuit representations can also be developed. The block diagram or equivalent circuits are determined entirely by the specific application. For problems where linear equations cannot be derived, general machine equations are used to develop analogue computer representations, and studies of nonlinear problems using computing machines are discussed.

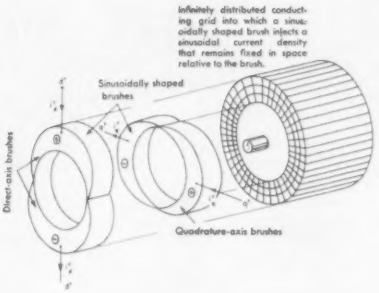
Infinitely distributed conducting grid into which a sinusoidally shaped brush injects a sinusoidal current density that remains fixed in space relative to the brush.
Sinusoidally shaped brushes
Direct-axis brushes
Quadrature-axis brushes

**Fig. 3. Idealized rotor structure for producing sinusoidally distributed current sheet on moving rotor, where current sheet is fixed, relative to brush axis. Rotor replaces that in Fig. 1 when analyzing commutator machines or using d-q variables.**

## THE LABORATORY

THE ANALYTICAL CONCEPTS of the previous sections are only effective teaching concepts if they can be utilized in in the laboratory. Laboratory work developed around conventional machines has not proved successful for exploiting the transformation theory or the idea of originating many mach ne types by constraints applied to one general physical structure. To exploit these ideas, a machine has been developed, which has a 2-phase winding on stator and a commutated winding on rotor (Fig. 4). The 4-brush assembly provides a 2-winding system in space quadrature on the rotor. The brush assembly can be rotated by a separate motor, and the brush leads are connected to the stator through slip rings. By driving the brush assembly, the rotor can be energized in any desired moving co-ordinate system. This machine can be constrained by applying currents, open or short circuits in any desired reference frame. Students carry out experimental programs as follows:

1. Measure machine parameters: inductances, resistances, inertia, and damping.
2. Operate as a d-c machine with direct current applied to one stator field and one pair of brushes; brushes fixed to stator.
   a. Evaluate electrical time constants of stator and rotor and mechanical time constant.
   b. Develop approximate block diagram for control.
3. Operate as a 2-phase induction motor; apply 2-phase voltages to stator and short circuit rotor circuits.
   a. Evaluate electrical and mechanical time constants.
   b. From the time constants show that electrical steady-state is a valid approximation for most dynamic studies; develop the equivalent circuit and speed–torque curves from general equations and verify experimentally.
   c. Develop approximate control representations.

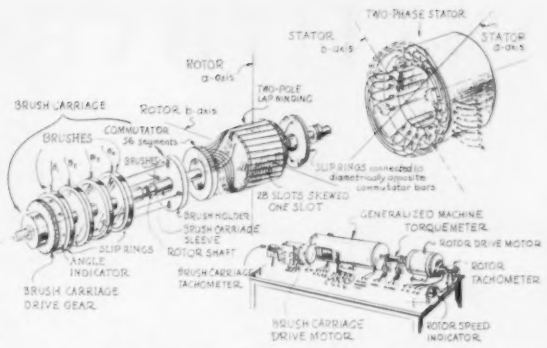


**Fig 4. Generalized rotating electromechanical energy converter. *Note:* Brush carriage can be driven separately, locked to the rotor, or locked to the stator.**

4. Apply the necessary constraints to generate the following standard machines:
   a. Synchronous machine
   b. Repulsion machine
   c. Transformer Metadyne
   d. S-generator Metadyne
5. Develop unconventional machines by constraints:
   a. Drive brushes at speed $\omega$ and apply a constant direct current to one set of brushes.
   b. Short circuit the stator through a resistance.
   c. Show that rotor turns in direction opposite to brush direction with speed determined by stator resistance.
   d. Correlate the observed performance with the equations of motion.

## CONCLUSIONS

THIS ARTICLE INDICATES how a unified approach can be made to the teaching of electromechanical energy conversion devices, particularly electric machinery. This approach includes both the field theory and circuit theory aspect as applied to the problem in a rigorous and scientifically palatable manner It also shows that the analysis of most machine types can be carried out from general differential equations for one generalized machine.

The strength of this undertaking lies in the decision not to train machinery specialists through a type-by-type detailed analysis process, but to teach a more compatible theory of circuits and fields in relative motion. The result is a teaching pattern that may not produce the equations for a specific machine in the first week of class, but one that will develop in the student a suitable background and an appreciation of the analysis problem for all machines.

A laboratory machine is shown which effectively demonstrates and supports the approach and indicates the common root that all machines basically have in a cylindrical structure with prescribed surface winding patterns.

## REFERENCES

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# INSTITUTE ACTIVITIES

## AIEE, IRE, and MSU Will Sponsor Midwest Symposium on Circuit Theory

THE SECOND MIDWEST SYMPOSIUM on Circuit Theory will be held at Kellogg Center, Michigan State University (MSU), Lansing, Mich., December 3–4, 1956.

The Symposium is being sponsored by the Circuit Theory Subcommittee of the Committee on Basic Sciences of AIEE, the Professional Group on Circuit Theory of the Institute of Radio Engineers, and the electrical engineering department of Michigan State University.

Four sessions, on the subjects of topology and circuit theory, systems analysis and synthesis, circuit theory and applications, and the place of circuit theory in education, will make up the program.

Dr. J. D. Ryder, dean of engineering, MSU, will deliver the banquet address, "Engineering Education for the Future."

The tentative technical program for the Symposium follows.

### Monday, December 3

**8:00 a.m. Registration**

**9:00 a.m. Opening Remarks**

Prof. Baccus, head of electrical engineering department, MSU

**9:15 a.m. Session I—Topology and Circuit Theory**

Chairman: L. A. Pipes, University of California, Los Angeles

**The Vertex, Circuit, Cut-set, and Tie-set Aspects of Linear Graphs.** *S. Seshu*, Syracuse University; *M. B. Reed*, MSU

**Kron's Method of Tearing and Its Applications.** *F. H. Branin, Jr.*, Shell Development Company

**Philosophy of the Network vs the Mathematical Theory of Networks.** *M. B. Reed*, MSU

**12:00 noon Lunch**

**1:30 p.m. Session II—Systems Analysis and Synthesis**

Chairman: M. Van Valkenburg, University of Illinois

**Time-Varying Sampled-Data Systems.** *B. Friedland*, Columbia University

**Schwarz Distributions.** *P. W. Ketchum*, University of Illinois

**Sensitivity Considerations in Active Network Synthesis.** *J. G. Truxal, I. Horowitz*, Polytechnic Institute of Brooklyn

**Synthesis of Minimum Phase Transfer Functions.** *R. H. Pantell*, University of Illinois

**6:30 p.m. Banquet**

**8:30 p.m. Address**

Introduction of Dean Ryder, J. J. Gershon, DeVry Technical Institute

Address: "Engineering Education for the Future" Dr. J. D. Ryder, dean of Engineering, MSU

### Tuesday, December 4

**8:30 a.m. Session III—Circuit Theory and Applications**

Chairman: L. Zadeh, Columbia University

**Systematic Method for Solving Feedback Amplifier Circuits.** *R. A. Sharpe*, Iowa State College

**Topological Graphs of Electromechanical Systems.** *H. E. Koenig, W. A. Blackwell*, MSU

**Equalization of Transistor Low Pass Amplifiers.** *H. Hellerman, C. R. Zimmer*, Syracuse University

**Patterns of Driving Elements Related to Tubes and Transistors.** *G. B. Reed*, MSU

**12:00 noon Lunch**

**1:30 p.m. Session IV—The Place of Circuit Theory in Education**

Chairman: W. Boast, Iowa State College

**The Place and Content of Circuit Theory Courses in the Electrical Engineering Curriculum.** *J. S. Johnson, E. M. Sabbagh, G. R. Cooper*, Purdue University

Panel Discussion
Moderator: W. R. LaPage, Syracuse University

## More than 5,000 Members and Guests Expected at 1957 Winter General Meeting

THE ANNUAL AIEE Winter General Meeting will be held January 21–25, 1957. There is every indication that more than 5,000 members and guests will again register for this meeting at the Hotels Statler and McAlpin, New York, N. Y.

#### Technical Sessions

It is a few weeks too early to report on the committees sponsoring technical sessions. However, it is presumed that most of the 49 committees in the 6 technical divisions will be represented. More detailed information will appear in the December issue of *Electrical Engineering*.

#### Hotel Reservations

The meetings will be held at the Hotels Statler (general headquarters) and the Sheraton McAlpin, the latter representing a change from the past two years. The Sheraton McAlpin is undergoing very extensive modernization of both meeting rooms and guest rooms. The Committee feels that members will find quite a difference in the atmosphere there than they may have experienced in earlier years.

Blocks of rooms have been set aside at both of these hotels as well as other hotels in the Pennsylvania and Grand Central zones as in past years, except that the Hotel Governor Clinton will not be able to offer accommodations in any way this year. Details concerning hotels and rates will appear in the December issue of *Electrical Engineering*.

The time of the meeting conflicts with two other large groups in 1957 and the hotel situation will be more stringent than has been experienced in the past several years. None of the hotels will guarantee any rooms not reserved prior to January 7, 1957. The Committee suggests that requests be received prior to Christmas, as it is much more likely that the hotel desired will be able to accept it at that time.

Members are asked to send reservations to the hotel of their first choice, specifically referring to the AIEE meeting. Do not write to more than one hotel. If requests cannot be filled, the hotel will automatically refer requests to the Hotel Accommodations Committee, which will endeavor to obtain a similar reservation at another of the Convention hotels. It is further suggested that reservations beginning on Sunday, January 20 have a better chance of being acted upon favorably than those for Monday or Tuesday.

#### Theater Tickets

Theater tickets will be provided for members who want to see stage shows. However, the committee under the chairmanship of S. Friend, Jr., feels it is inadvisable at this time to give a specific listing of shows that will be playing during the meeting. A complete listing of shows is scheduled for the December issue, and it is requested that all inquiries be deferred until that time.

*Informal Tea*

This social gathering before the formal program begins has been enjoyed by more and more people each year. Make it a point to attend this year—Sunday afternoon, January 20, from 4 to 6 p.m., in the Georgian Room of the Statler. There will be no charge.

During this period the registration facilities will be open for those wishing to avoid the Monday morning rush.

Tickets to available radio broadcasts and television shows will be provided at the time of registration.

#### Smoker

A highlight of the Winter General Meeting will be the Smoker to be held Tuesday evening, January 22, 1957. Good food, good fellowship, and top quality entertainment will be the feature of this event which will take place in the Hotel Statler.

Attendance will be limited for the comfort of guests and ticket requests should be mailed at an early date. These requests should be addressed to AIEE Smoker Committee at 33 West 39 Street, New York 18, N. Y. When the price has been determined (see December *Electrical Engineering*) checks should be made payable to "Special Account, Secretary, AIEE" and sent to the same address.

#### Dinner-Dance

A Dinner-Dance will be held Thursday evening, January 24, in the Grand Ballroom of the Hotel Statler. General arrangements will be the same as those which proved enjoyable last year. Dress will be formal. Write soon for reservations at tables for 10. Address requests to AIEE Dinner-Dance Committee at 33 West 39 Street, New York 18, N. Y. When the price has been determined (see December *Electrical Engineering*) checks should be made payable to "Special Account, Secretary, AIEE" and sent to the same address.

#### Inspection Trips

A program of 18 inspection trips is being prepared which will include not only the more popular trips of the past, but also several trips which have not been offered at a Winter General Meeting within the last 7 years.

Some of the old stand-bys, which are oversubscribed every year, are trips to Radio City Music Hall, Brookhaven National Laboratory, and the Merchant Marine Academy. A few of the new trips which are contemplated are visits to the Grumman Aircraft Engineering Corporation, The New York Coliseum, and the Fisher Radio Company of Long Island City, N. Y.

#### Ladies Entertainment

The Ladies Entertainment Committee under the able leadership of Mrs. C. T. Hatcher, is planning a varied and enjoyable program for the visiting guests.

Morning Coffee Hour will start each day at Ladies Headquarters. A "Get-Acquainted" Tea is scheduled for Monday, January 21, with the remainder of the week being filled with interesting tours, lovely luncheon-style show, and a dinner with a floor show.

Please note that each lady must bring her badge to Ladies Headquarters after registering with her husband before she can register for the program and entertainment. Headquarters will be located in the Washington Room of the Statler.

#### Winter General Meeting Committee

Members of the 1957 Winter General Meeting Committee are: D. M. Quick, chairman; R. T. Weil, Jr., vice-chairman; J. J. Anderson, secretary; L. F. Stone, budget co-ordinator and AIEE vice-president for District 3; W. R. Clark, chairman, Technical Operations Department; F. S. Black, Public Relations; W. A. Clark, General Session; D. V. Buchanan, Hotel Accommodations; F. L. Williams, Registration; J. A. Mulligan, Inspection Trips; R. R. Meola, Monitors; H. B. Snow, Smoker; W. F. Anselm, Dinner-Dance; S. Friend, Jr., Theater and Broadcast Tickets; Mrs. C. T. Hatcher, Ladies Entertainment; A. J. Cooper, Ex-Officio member (Past-Chairman).

# VDI Celebration Commemorates 100 Years of German Engineering

R. W. SORENSEN
FELLOW AIEE

THE VEREIN DEUTSCHER INGENIEURE (VDI) celebration in Berlin, Germany, was a great event. For the engineers of Germany it was the climax of a series of nation-wide programs held during 1956 declaring the achievements of 100 years of organized engineering in Germany. It also presented ideas to encourage at future anniversary commemorations even greater results in providing materials and devices, and in making engineers realize that it is their moral obligation to help provide for all people a better and happier living during the next engineering century by participation in activities relating to the philosophical, political, and spiritual guidance of the country. Visiting engineers from over all the world experienced a delightful revelation of German courage, accomplishment, and hospitality. It is well that AIEE and other United States engineering societies were represented by official delegates. Their absence would have been an opportunity lost to prove to engineers assembled there that United States engineers are deeply interested in working with others toward having engineering methods and devices used to raise material and ethical living standards to a level that will convince all men that win or lose, war means only destruction.

The Board of Directors honored me by asking that I represent AIEE at this celebration in Berlin. In accepting the invitation I thought I might repay the Institute a small part of the huge debt I owe it for the technical aid it has been to me, and for its other activities which have provided the friendship of many noted engineers and their families. The Berlin meeting, however, was so rich in professional and social gains as to put me further in debt to the Institute.

A few days spent in Munich, on the way to West Berlin, proved to be excellent preparation for my Berlin visit. While my wife and I were there, friends showed us many things of interest, and showered us with German hospitality. They and many others by their actions completely contradicted information previously given us indicating that Americans might not be well liked by Germans. Most definitely we think the Germans are more than willing to meet American tourists as friends, and are very appreciative of the aid the United States gave them during their recent reconstruction period.

This article is a personal account by Dr. Sorensen of the Verein Deutscher Ingenieure (VDI) Centennial Celebration held in Berlin, Germany, May 12–15, 1956. Dr. Sorensen and his wife attended the program during their recent tour of Europe.

The Munich Deutsches Museum, which celebrated its 50th Anniversary in 1953, provided an educational review of our knowledge of early engineering as practiced by Germans. This prepared us well for understanding what we were to hear in Berlin. Electrical engineering productions, of course, did not date back 100 years, but their parents made by physicists and mathematicians did, as did the many mechanical exhibits. One of the older electrical exhibits, a Warner electric locomotive built in 1879, had for its neighbor a steam locomotive built in 1813.

Tuesday, May 11 at 11 a.m., we were in a very old hotel in Munich, and at 3 p.m. we were in a modern Berlin hotel where small but comfortable rooms with fold-away beds and other appointments, identical equivalents of those found in our ultra-modern hotels, were obtainable. Dr. and Mrs. R. C. Burt of Pasadena, Calif., another AIEE couple, were in the next room. Dr. Burt informed us that although the celebration would not begin until the next day, acquaintance parties were already under way and we proceeded to discuss plans to attend them. Prof. E. C. Keachie, a member of the University of California mechanical engineering faculty at Berkeley, who for the 1955–56 year is a Fulbright scholar and guest professor at the Technische Hochscule, Darmstadt, Germany, joined us. We three, with our wives, were a considerable part of the United States citizens group attending the celebration. Others were Dr. Lillian Gilbreth; R. C. Allen of the Allis-Chalmers Company; Gen. S. E. Reimal, representing Engineers Joint Council; R. H. Bacon, president, R. H. Bacon Company, and Mrs. Bacon from Chicago, Ill., representing American Society of Mechanical Engineers (ASME); R. H. Morris, president of American Institute of Plant Engineers and editorial director of *Power Engineering* and Mrs. Morris; and Mr. Kramer, assistant to Mr. Morris.

The acquaintance program of the day ended with all the U. S. delegates being guests of VDI at an indoor German Beer Garden Party at the Pralat Schoneberg where much conversation and good music were enjoyed.

The programs supplied upon registration informed us that the official start would be made the next morning, Saturday, May 12, at 9:30 a.m. However, we learned that the regularly scheduled session would be preceeded by a 9 a.m. dedication of a replica of the original statue "The Engineer." Men who new prewar Germany informed us that the original, a symbol of the engineering

*Courtesy R. H. Morris*

**DURING THE VEREIN DEUTSCHER INGENIEURE Celebration, (*left to right*) VDI President Schuberth greets United States delegates Dr. Molineaux, American Society of Civil Engineers (ASCE) and R. W. Sorensen, AIEE. In back of Dr. Sorensen is Prof. E. C. Keachie, University of California. R. C. Allen (*right*) of Milwaukee, Wis., looks on.**

profession for years, graced the old VDI headquarters building that is in the East Berlin Russian Zone. The dedication address was made by E. Kothe, a director of VDI, a man greatly revered as the grand old man of the profession. At the close of his talk several young engineers made remarks of praise and appreciation, then presented him with some select books.

The first discussion of the regular program, which followed the official welcoming address, was given by Prof. Dr. R. Viewig, president of the Physics-Technical University. In his speech, he often mentioned Einstein as he developed an interesting presentation of the relation between science and practical technology. Dr. Viewig was followed by F. Bauer who discussed the applications of engineering technique. During the afternoon, there were two parallel sessions with three papers each. One was devoted to research and development, and the other to design and construction. Nuclear energy and its influence upon research and development and upon materials and processes was emphasized as henceforth being a major factor in all engineering operations. The design and construction papers dealt to considerable extent with model tests, lightweight construction, and beauty of design. The next item on the program, "Berliner Abend" to be held at 8 p.m., might be translated "an evening in Berlin." This event was held at the Festival Hall. No exact count of the number present was available but it was estimated that the 3,000 men and 1,000 women attending the anniversary celebration were present on this occasion. Entertainment was provided in two large halls by opera stars, vaudeville acts, and a boy's choir, as well as good orchestra music at proper intervals. An unusual feature was an excellent children's ballet performance.

**A REPLICA of the statue "The Engineer," a symbol of the engineering profession for many years in Germany, was dedicated at ceremonies held during the Verein Deutscher Ingenieure Celebration in Berlin, Germany.**

Between the close of the afternoon meetings and the "Berlin Night," a social hour was sponsored by VDI at the Hotel Gerhaus for the official delegates, VDI officials, and foreign visitors—about 200 were present. At this time, official testimonials of the various societies were placed in the hands of VDI officials. These presentations were so many that individual presentation would have required a very lengthy program.

The General or Grand Assembly was held Sunday morning, May 13, at 10 a.m. in the main room of the Festival Hall with about 4,000 present. The session opened and closed with music by the Berlin Festival Orchestra. Guests were welcomed by Dr. Suhr, acting Mayor of Berlin, and Dr. Blucher. Dr. H. P. Schuberth, VDI president, then spoke at some length on the history of VDI and its future. This was followed by public presentation of the tributes from societies outside of Germany. The principal address, delivered by Prof. Dr. Pfender, dealt with the subject, "Man and His Technology." Those who understood German thoroughly reported that it was a brilliant discussion of the relationship of religion, philosophy, and technology as viewed from the human side. This talk was followed by a whole series of presentation speeches accompanied by certificate and medals mostly given to German engineers who had done outstanding work. We were pleased to note that Dr. Gilbreth, one of the non-German recipients, was given a real ovation when she received a VDI medal for outstanding research into motion problems. Following this program, the delegates and medal men were given a complimentary luncheon at the Hotel Gerhaus. Dr. Gilbreth's speech of acceptance at dinner was a heartwarming talk which she began in German and finished in English. We were told that the book "Cheaper by the Dozen" is one of the biggest sellers in Germany.

Monday morning's program provided two lectures. Dr. H. H. Kumpke discussed the social effects of technology, and Prof. Dr. S. Struger spoke on the subject, "The Laws of the Spirit." Both discussions, as evidenced by the subjects, dealt with the influence of technology on human relations. In fact, it was interesting to note that throughout the whole program there was much attention given the relation of religion, philosophy, psychology, and human relations to the practice of engineering.

Monday afternoon, May 14, provided two parallel sessions of three papers each. At the one meeting the theme was "Manufacturing" and at the other the theme was

"Distribution of Goods." The papers on "Manufacturing" dealt with (1) principles of fabrication, (2) flow of material—automation first steps, and (3) complete automation. "The Distribution of Goods" papers discussed (1) the engineer's part for the future in goods distribution, (2) leadership and executive ability, and (3) industrial patent protection.

The entire Congress was devoted to the uses of engineering as a part of the political, economic, and spiritual life of the nation with a striking lack of information in the form of technical data or calculation.

The program for the celebration included a great quantity of information besides the papers described, which related to many exhibits and factories that were open to visitors. It was this author's privilege to take advantage of some of these. One was a visit to the Siemens-Schuckertwerke (factory) where research is carried on and power equipment is manufactured. Another was to a museum, and a third was to a portion of Soviet controlled East Berlin. Also, during the four days mentioned there was opportunity for walking tours and bus tours in and around West Berlin. On May 15 long tours were in order, the East Berlin visit being part of one of them. When the men were busy, the well-planned women's program enabled the wives to gather much information regarding life in Berlin. The later discussions added much to my knowledge of how the Germans are now living. My wife and I found all this of such great interest that we stayed in Berlin another day for touring the city and visiting with its residents.

The VDI membership before the war was about 60,000. Many branches of engineering were represented but the mechanical engineers outnumbered any of the other classifications. There are now about 30,000 members, 3,000 of whom attended the Berlin celebration. This attendance was supplemented by a goodly number of engineers from other countries and 1,000 wives and relatives of attending engineers.

As is usual at affairs of this sort, much of the value of attendance is the opportunity to compare and exchange information with persons from many lands. The lack of knowledge of the German language on the part of the Americans present was most noticeable. This lack made each of us very dependent upon one another for such benefit as we could obtain from the technical papers presented which, though obtainable, were printed in German only. Indeed, we were also very dependent upon citizens from other countries who could speak German and English fluently. In this regard, we, from the United States, were often put to shame by Europeans who could speak fluently four or more languages.

We are particularly appreciative of the aid given us by R. H. Bacon, president of R. H. Bacon Company, whose account of his experience was published on page 682 of *Mechanical Engineering*, July 1956 and to R. H. Morris, editorial director, *Power Engineering*, who gave an account of his experience in the October issue of *Power Engineering*. Both of these men helped me gather much information about the meetings.

Earlier in this account mention was made of evidence of German courage and accomplishment. Except for some scars of the war, all of West Germany seems to be back at about the same living level as before the war. Work is plentiful, there is a great shortage of engineers even as in the United States. Housing still is short but there are many fine apartment buildings being erected. One information source said that in the Western Zone almost 300 were built in 1955 with only one being built in the Eastern Zone during the same period.

Our general impression was that although East Berlin was not a part of the nation, Germany is well on the way again to being a foreward looking great nation, but perhaps without the motto "Deutschland über alles" (Germany Over All). Contemplating this, it is to be hoped that the fears of some of its neighbors that a united Germany may produce another dictator will never be realized.

Our brief visit to East Berlin, together with our observation of renegade visitors who found ways to visit West Berlin, disclosed eye and ear evidence that the limited signs of comfort and prosperity, presented in the form of buildings, are show spots only. They are counterbalanced many times over by evidences of the lack of good governmental housekeeping and the sad spectacles of human misery.

Those who desire may obtain German language papers presented at the celebration from the Verein Deutscher Ingenieure, Prinz-Georg-Strasse 77/79 Dusseldorf, Germany.

## Program Set for 1956 Computer Conference

The 1956 Eastern Joint Computer Conference, which will meet December 10–12 at the Hotel New Yorker and adjoining Manhattan Center in New York, N. Y., has announced that some 28 technical papers will be presented by the foremost computer authorities.

Leading manufacturers of computers and associated products will exhibit their equipment to an anticipated record attendance of engineers and management executives.

Registration fee at the conference is $5 for members of the three sponsoring societies, AIEE, Institute of Radio Engineers, and Association for Computing Machinery, and $8 for nonmembers. Advance registration, geared to save registrants time and effort, is $4 for members, $7 for nonmembers. All will receive a free copy of Proceeding of the Computer Conference.

For advance registration forms, write to 1956 Eastern Joint Computer Conference, Box 1599, Grand Central Station, New York 17, N. Y.

The tentative technical program follows.

### Monday, December 10

#### Morning Session

J. W. Leas, session chairman

Welcome: J. R. Weiner, Conference chairman

Introduction and Keynote: H. T. Engstrom, National Security Agency

**New Computer Developments Around the World.** *E. S. Calhoun*, Stanford Research Institute

**Evaluation of New Computer Components, Equipments, and Systems for Naval Use.** *L. D. Whitelock*, Bureau of Ships

### Future AIEE Meetings

**Fall Textile Conference***
North Carolina State College, Raleigh, N. C.
November 1–2, 1956

**AIEE-IRE-ISA Conference on Electronic Technology in Medicine and Biology***
Hotel McAlpin, New York, N. Y.
November 7–9, 1956

**AIEE-IRE-MSU Midwest Symposium on Circuit Theory***
Michigan State University, Lansing, Mich.
December 3–4, 1956

**AIEE-IRE-ACM Eastern Joint Computer Conference***
Hotel New Yorker, New York, N. Y.
December 10–12, 1956

**AIEE-IRE-RETMA-ASQC Symposium on Reliability and Quality Control**
Hotel Statler, Washington, D. C.
January 14–16, 1957
(*Final date for †TP—closed, ‡CP Syn.—Nov. 1, CPMs—Nov. 9*)

**Winter General Meeting**
Hotel Statler, New York, N. Y.
January 21–25, 1957
(*Final date for †TP—closed, ‡CP Syn.—Nov. 8, CPMs—Nov. 16*)

**AIEE-IRE-U of P Conference on Transistor and Solid State Circuits**
Philadelphia, Pa.
February 14–15, 1957
(*Final date for †TP—Nov. 16, ‡CP Syn.—Nov. 30, CPMs—Dec. 12*)

**AIEE-IRE-ACM Western Joint Computer Conference**
Hotel Statler, Los Angeles, Calif.
February 26–28, 1957
(*Final date for †TP—Nov. 29, ‡CP Syn.—Dec. 14, CPMs—Dec. 24*)

**Textile Conference**
Georgia Institute of Technology, Atlanta, Ga.
March 7–8, 1957
(*Final date for †TP—Dec. 7, ‡CP Syn.—Dec. 22, CPMs—Jan. 2*)

**EJC Nuclear Engineering and Science Congress**
Convention Hall, Philadelphia, Pa.
March 11–15, 1957
(*Final Date for †TP—Dec. 12, ‡CP Syn.—Dec. 27, CPMs—Jan. 4*)

**AIEE-ASME Engineering Management Conference**
Pittsburgh, Pa.
March 27–28, 1957
(*Final date for †TP—Dec. 28, ‡CP Syn.—Jan. 11, CPMs—Jan. 22*)

**Southern District Meeting**
Hotel Heidelberg, Jackson, Miss.
April 3–5, 1957
(*Final date for †TP—Jan. 3, §DP Syn.—Jan. 20, DPMs—Jan. 30*)

*Final date for submitting papers—closed
†**TP**—Transactions paper
‡**CP Syn.**—Conference Synopsis
**CPMs**—Conference Manuscript
(The CPSyn. date is 10 days before the CPMs date)
§**DP Syn.**—District Synopsis
**DPMs**—District Manuscript
(The DPSyn. date is 10 days before the DPMs date)

### Afternoon Session—New Systems

Prof. Norman Scott, Session chairman

**The TRANSAC S-1000 Computer.** *J. L. Maddox, J. B. O'Toole, S. Y. Wong,* Philco Corporation

**A Transistor Computer with a 256 by 256 Memory.** *J. L. Mitchell, K. H. Olsen,* Lincoln Laboratory

**Design Objectives for the IBM STRETCH Computer.** *S. W. Dunwell,* IBM Research Laboratory

**A New Large Scale Data Handling System—DATAMATIC 1000.** *R. M. Bloch, W. C. Carter, E. J. Dieterich, J. E. Smith,* Datamatic Corporation

**The TRADIC LEPRECHAUN Computer.** *J. A. Githens,* Bell Telephone Laboratories, Inc.

**Functional Description of the NCR 304 Data Processing System for Business Applications.** *M. S. Shiowitz, A. A. Cherin, M. J. Mendelson,* Norden-Ketay Company

## Tuesday, December 11

### Morning Session—Circuits and Components

T. A. Kalin, Session chairman

**Ambient Approach to Solid-State Computer Components.** *J. K. Hawkins,* Logistics Research

**A Magnetically-Controlled Gating Element.** *D. A. Buck,* Lincoln Laboratory

**A 2.5 Megacycle Ferractor Accumulator.** *T. H. Bonn, R. D. Torrey,* Remington Rand Univac

**High-Temperature Silicon-Transistor Computer Circuits.** *J. B. Angell,* Philco Corporation

**A Saturable-Transformer Digital Amplifier with Diode Switching.** *E. W. Hogue,* National Bureau of Standards

**High Speed Transistor Computer Circuit Design.** *R. A. Henle,* IBM Research Laboratory

### Noon—Luncheon

### Afternoon Session—Input-Output Devices

W. H. Burkhart, Session chairman

**An Automatic Input for Business Data Processing Systems.** *K. R. Eldredge, F. J. Kamphoefner,* P. H. *Wendt,* Stanford Research Institute

**The Burroughs Electrographic Printer-Plotter for Ordnance Computing.** *Herman Epstein, Paul Kintner,* Aberdeen Proving Grounds

**A Transistorized Transcribing Card Punch.** *C. T. Cole, K. L. Chien, C. H. Propster,* Radio Corporation of America

**Apparatus for Magnetic Storage on Three-Inch Wide Tape.** *R. B. Lawrance, R. E. Wilkins, R. A. Pendleton,* Datamatic Corporation

**Synchronization of a Magnetic Computer.** *J. Keilson, G. Smoliar,* Remington Rand Univac

## Wednesday, December 12

### Morning Session—High-Speed Memories

Prof. Morris Rubinoff, Session chairman

**A Technique for Using Memory Cores as Logical Elements.** *L. Andrews,* National Cash Register Company

**Recent Developments in Very High-Speed Magnetic Storage Techniques.** *W. W. Lawrence,* IBM Research Center

**A Low-Cost Megabit Memory.** *R. A. Tracy,* Burroughs Corporation Research Center

**A Compact Coincident-Current Memory.** *A. V. Pohm, S. Rubens,* Remington Rand Univac

**A Cryotron Catalog Memory System.** *A. E. Slade,* Arthur D. Little, Inc.

### Afternoon Session—Random Access Memory Files and Conference Summary

John Howard, Session chairman

**The Datafile—A New Tool for Extensive File Storage.** *D. N. MacDonald, C. L. Ricker,* ElectroData Corporation

**Engineering Design of a Multiple Access Storage System (MASS).** *M. L. Greenfield,* Telecomputing Corporation

**A Large-Capacity Drum File.** *V. J. Porter, H. F. Welsh,* Remington Rand Univac

**System Organization of the IBM 305.** *M. L. Lasser, J. W. Haanstra,* IBM Laboratory

Conference Summary—J. W. Carr, III

# Past Chairman Honored

S. C. TOWNSEND (*right*), manager of the atomic power department, Pennsylvania Power and Light Company, Allentown, Pa., and past chairman of the Lehigh Valley Section of the AIEE, receives past Chairman certificate and pin from F. S. Fehr, Reading, Pa., (*second from left*), chairman of the Lehigh Valley Section. Presentation took place at the Hazleton, Pa., Division Meeting at which A. J. Mustard (*left*), of Eastern Air Lines, gave a lecture on "Aircraft Electric Circuitry and Instrumentation." W. F. MacKenzie, Jr., Hazleton Division chairman (*second from right*) looks on.

# Nominations for 1957 Election of AIEE Officers

For the nomination of officers to be voted upon in the spring of 1957, the AIEE Nominating Committee will meet in New York, N. Y., January 21, 1957. The officers to be elected are: a president, a treasurer, three directors, and five vice-presidents, one from each of the even-numbered geographical Districts. Fellows only are eligible for the office of president; Members and Fellows for the offices of vice-presidents, directors, and treasurer.

To guide this committee in performing its constituted task, suggestions from the membership are, of course, highly desirable. To be available for consideration of the committee, all suggestions must be received by the secretary of the committee at Institute headquarters not later than December 14, 1956.

In accordance with the provisions in the constitution (C) and bylaws (B), quoted in the following paragraphs, actions relating to the organization of the Nominating Committee are now under way:

**Constitution**

C-30. There shall be constituted each year a Nominating Committee consisting of one representative of each geographical District, elected by its executive committee, one representative of each technical division elected by the division committee, and other members chosen by and from the Board of Directors not exceeding in number the number of technical divisions; all to be selected when and as provided in the Bylaws. The Secretary of the Institute shall be the secretary of the Nominating Committee, without voting power.

C-31. The executive committee of each geographical District shall act as a nominating committee of the candidate for election as vice-president of that District, or for filling a vacancy in such office for an unexpired term whenever a vacancy occurs.

C-32. The Nominating Committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The Nominating Committee shall name, on or before January 31 of each year, one or more candidates for president, treasurer, and the proper number of directors, and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical Districts, if received by the Nominating Committee when and as provided in the Bylaws; otherwise the Nominating Committee shall nominate one or more candidates for vice-president(s) from the District(s) concerned.

**Bylaws**

B-27. During September of each year, the secretary of the Nominating Committee shall notify the chairman and secretary of the executive committee of each geographical District, and the chairman and secretary of each technical division committee, that, by December 15 of that year, each District and each technical division should select a representative to serve as a member of the AIEE Nominating Committee and an alternate to serve if the representative is unable to attend the meeting of the Nominating Committee. The names of representatives and alternates, so selected, should be transmitted by the above designated officers to the secretary of the Nominating Committee by December 15.

During September of each year, the secretary of the Nominating Committee shall notify the chairman and secretary of the executive committee of each geographical District in which there is, or will be during the year, a vacancy in the office of vice-president that by December 15 of that year, a nomination for a vice-president in that District made by the District executive committee

should be in the hands of the secretary of the Nominating Committee.

Between October first and December fifteenth of each year, the Board of Directors shall choose a number of its members, not exceeding the number of technical divisions, to serve on the Nominating Committee, and notify the secretary of the Nominating Committee of the names of the members so chosen.

The secretary of the Nominating Committee shall give the members so selected not less than 10 days' notice of the first meeting of the committee, which shall be held not later than February 15, 1957. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. To insure that full consideration be given to all suggestions from the general membership, they must be in the hands of the secretary of the committee by December 15, 1956. The nominations as made by the Nominating Committee shall be published in the March issue of *Electrical Engineering*, or otherwise mailed to the Institute membership not later than the first week in March.

Independent nominations may be made in accordance with provisions in article VI, C-33, of the constitution and B-28 of the Bylaws, which are quoted in the following:

**Constitution**

C-33. Independent nominations may be made by a petition of twenty-five (25) or more corporate members sent to the secretary when and as provided in the Bylaws; such petitions for the nomination of vice-presidents shall be signed only by members within the District concerned.

B-28. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with C-33 must be received by the secretary of the Nominating Committee not later than March fifteenth of each year, to be placed before that committee for the inclusion in the ballot of such candidates as are eligible.

28.1 The candidates shall appear on the ballot, grouped alphabetically under the name of the office for which each is a candidate. The voting in each case shall be restricted to the nominees printed on the ballot.

28.2 The ballot shall provide a place where the entire slate of nominees can be voted with a single mark, if there is no choice to be made between any of the candidates. The balloting should be secret in the case of a contest. The ballots shall be checked for ineligible voters only in the case of a contest.

28.3 The Tellers' Election Report shall give the sum total of the ballots received and shall designate this total as a vote for the entire slate of officers where there are no alternative candidates. Only in the case of a contest shall an individual count be made.

28.4 The President shall decide the number of Tellers for each election. The Secretary is authorized to prepare the ballot for counting on a business machine where feasible.

(*Signed*) N. S. Hibshman
*Secretary*

## Program on the Science of Transistor Circuit Design Planned

A tutorial series and study program on "The Science of Transistor Circuit Design" will be sponsored by the Basic Science Division of the New York Section of AIEE.

The program will be held on six successive Tuesday evenings, November 13 to December 18, 1956, from 6:30 to 9:00 p.m., at the Western Union Auditorium, 60 Hudson Street, New York, N. Y.

The topics scheduled are Network Representations, R. L. Pritchard, General Electric Company, November 13; Power Transistor Circuit Design and Limitations, L. Vallese, Polytechnic Institute of Brooklyn, November 20; Stability Considerations in Transistor Amplifiers, T. O. Stanley, Radio Corporation of America, November 27; High Frequency Design Considerations, L. Schimpf, Bell Telephone Laboratories, December 4; Transistor Logic Circuits, M. Rubinoff, University of Pennsylvania, December 11; and Synthesis of Active Circuits Using Transistors, I. Horowitz, Polytechnic Institute of Brooklyn, December 18.

For further information and advance registration, write to Moe Wind, Polytechnic Research and Development Company, Inc., 202 Tillary Street, Brooklyn 1, New York.

The registration fee is $3 for AIEE members, $6 for nonmembers. Make checks payable to Basic Science Division, New York Section, AIEE.

## New Staff Position Open at AIEE Headquarters

AIEE is seeking a member to join its full-time staff at Headquarters. The introduction of the new departmental type organization has created the need for a staff man to serve as Secretary to the Professional Development and Recognition Department in which the major operational activity is conducted by the Student Branches Committee. Reference to page 858 in the September 1956 issue of *Electrical Engineering* will show the committees grouped in the Professional Development and Recognition Department. The names of these committees summarize the objectives of the Department. It seeks to promote the professional development of the individual electrical engineer from the time he begins to think about choosing his career, until the mature years when his work is being evaluated by his peers and accorded recognition.

The Staff Manager or Secretary for this Department will be responsible for much of the co-ordination of these efforts. However, his major responsibility will be in the promotion of the educational work of the Institute through its Student members and Student Branches. The work will be varied and interesting. It will be partly promotional, organizational, writing, and editing.

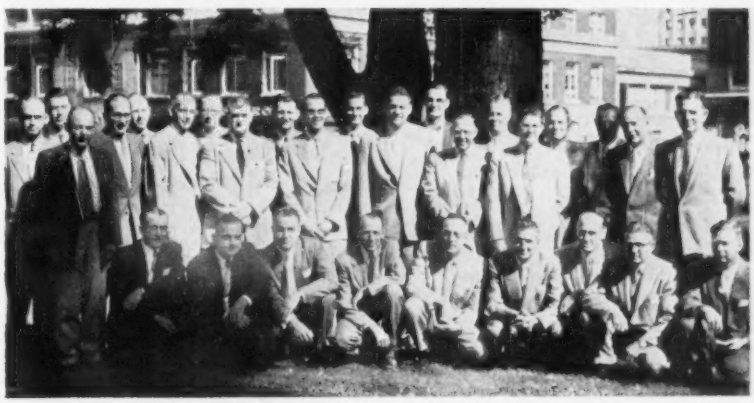
The ideal experience would be several years on an electrical engineering faculty, plus technical writing or general journalism, plus sales experience or personnel administration or association management. The likelihood of finding all of this experience in one relatively young man is recognized as definitely remote. However, the Secretary of the Institute would like to hear from any member who is interested in trying his hand at the job.

Write to:

N. S. Hibshman, Secretary
American Institute of Electrical Engineers
33 West 39th Street
New York 18, N. Y.

The pay is competitive in the present market. Headquarters is in New York City. Travel should not take more than 25 per cent of the time.

## North West District Executive Committee



*Courtesy C. B. Brown*

**THOSE PRESENT at the North West District Executive Committee Meeting in Portland, Ore., September 14, 1956, included *(kneeling, left to right)* A. Thommasen, chairman, Vancouver Island Subsection; E. C. Starr, Portland, Sections Committee; H. Arnett, Portland, secretary, North West District; M. M. Ewell, Portland, vice-president; E. B. Hedberg, chairman, Medford Subsection; R. B. Carter, chairman, Vancouver Section; J. G. Kirwan, vice-chairman, Portland Section; C. R. Kingsbury, chairman, Seattle Section; R. F. Dumford, Montana State College, chairman North West District Committee on Student Activities; *(standing, left to right)* R. M. Gilbert, Spokane, vice-chairman Membership Committee; J. D. Fox, chairman, Spokane Section; J. A. Davis, chairman, Utah Section; C. H. Staff, chairman, Tacoma Subsection; P. C. Magnusson, chairman, Eugene Subsection; H. A. Carlberg, vice-chairman, Richland Section; C. R. Beitman, chairman, Billings Subsection; W. J. Wheeler, chairman, Montana Section; A. E. Opdenweyer, chairman, Portland Section; H. L. Baker, secretary-treasurer, Montana Section; E. W. Hendron, secretary-treasurer, Utah Section; E. M. Lee, secretary-treasurer, Seattle Section; P. W. Worthen, chairman, Boise Subsection; G. M. Clifton, chairman, 1957 Pacific General Meeting, Richland Section; S. G. Yates, Spokane Section; M. M. Dye, chairman, Eastern Idaho Subsection; R. C. Hoffman, chairman, Richland Section; C. B. Brown, Montana Section; G. J. Henrikson, vice-chairman, Vancouver Section; and H. R. Hughes, Richland Section. R. E. Kistler, Seattle, director, also attended the meeting.**

# Conference Papers Open for Discussion

Conference papers listed below have been accepted for AIEE *Transactions* and are now open for written discussion until November 26. Duplicate double-spaced typewritten copies of each discussion should be sent to Edward C. Day, Assistant Secretary for Technical Papers, American Institute of Electrical Engineers, 33 West 39th Street, New York 18, N. Y., on or before November 26.

**56-660** **Salient Electrical Features of Muskingum River Plant.** *V. P. Rader, C. P. Zimmerman*

**56-708** **Big Bend–Granite Falls 230-Kv Transmission Line.** *T. M. Austin*

**56-709** **Transmission Planning for Mountain Sheep–Pleasant Valley Project.** *W. A. Morgan, G. R. George, R. C. Guse, M. F. Hatch*

**56-771** **Refinements in Design of Steam-Electric Generating Stations.** *J. L. Cohon*

**56-937** **The Synchronous Double-Fed Induction Machine.** *R. E. Bedford*

**56-943** **Carbon Brush Capacity Calculations.** *J. G. Wilhite*

**56-946** **Speed Control of Induction Motors Using Saturable Reactors.** *P. L. Alger, Y. H. Ku*

**56-948** **Electric Shock Hazard Analysis.** *K. S. Geiges*

**56-973** **Lightning Protection of Unit-Connected Turbine Generators—Field and Laboratory Studies.** *A. P. Hayward, J. K. Dillard, A. R. Hileman*

**56-991** **A New 115-Kv 1,000-Mva Gas-Filled Circuit Breaker.** *C. F. Cromer, R. E. Friedrich*

**56-992** **Interruption of Capacitance Charging Currents in Sulfur Hexafluoride.** *T. E. Browne, Jr., A. P. Strom*

**56-995** **Excitation Voltage Response Definitions and Significance in Power Systems.** *M. Temoshok, F. S. Rothe*

**56-997** **Steam Station Auxiliary Systems for Large High-Pressure Turbine-Generator Units.** *A. C. Dolbec, J. J. Heagerty, A. G. Mellor*

Preprints may be purchased at 40¢ each to members, 80¢ each to nonmembers, if accompanied by remittance or coupons. Please order by number and send remittance to: AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

## Papers Called for by AIEE-IRE-U of P Conference

Papers on transistor and solid state circuits are wanted by the 1957 AIEE-IRE-U of P Conference on Transistor and Solid State Circuits, February 14–15, 1957, Philadelphia, Pa.

Deadline for submission of 100 word abstracts is November 5, 1956. Please send abstract to: George H. Royer, Westinghouse Electric Corporation, 356 Collins Ave., Pittsburgh 6, Pa.

**Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. N. S. Hibshman, Secretary, 33 West 39th Street, New York 18, N. Y.**

# COMMITTEE ACTIVITIES

EDITOR'S NOTE: *This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.*

### General Applications Division

**Committee on Domestic and Commercial Applications** (H. F. Hoebel, *Chairman;* G. E. Schall, Jr., *Vice-Chairman;* J. A. Deubel, *Secretary*). This Committee, with a number of new members, is looking forward to a productive and interesting year. A technical session will be sponsored at the Winter General Meeting at which the Committee hopes to present a cross-section of activities by having papers from all four of the subcommittees. This should lead to an absorbing meeting.

Interest in the subject of electric space heating and heat pumps remains high in all parts of the country. Considerable work is being done on the West Coast, in particular, on the engineering and economic aspects of electric resistance heating for homes, apartments, and commercial premises. The Electric Space Heating and Heat Pumps (West) Subcommittee sponsored sessions at the Pacific General Meeting on this subject for the past few years. We intend to continue this practice.

The Committee is following with a great deal of interest the various discussions and studies which have been made recently on the question of higher secondary voltages for utilization equipment. This is of particular interest to the Domestic Appliance Subcommittee because of the great effect any material increase in voltage would have on the engineering design, performance, and safety of appliances. A discussion of the subject is planned at future Technical Conferences sponsored by this Subcommittee.

For the past several years, both the Farm Electrification Subcommittee and the Domestic Appliance Subcommittee have sponsored separate Technical Conferences in various parts of the country. These Conferences, given once a year, have presented and discussed items of current interest to electrical engineers in these fields. They have been very well attended and we hope to continue holding such meetings.

### Power Division

**Committee on Substations** (W. S. Scheering, *Chairman;* J. A. Smith, *Vice-Chairman;* A. F. Sedgwick, *Secretary*). The Committee on Substations now has eight projects which are being actively carried on.

Revision of American Standard *C37.2-1945*—Automatic Station Control, Supervisory and Associated Telemetering Equipments, which was assigned to the Automatic and Supervisory Control Subcommittee has now been approved by the ASA Sectional Committee C37 and should be published in the near future.

A Working Group on Voltage Gradients through the Earth under Fault Conditions has been formed with liaison representation from the Committee on Transmission and Distribution and the Committee on Protective Devices.

A new working group comprising members

### Bimonthly Publications

The bimonthly publications, *Communication and Electronics*, *Applications and Industry*, and *Power Apparatus and Systems*, contain the formally reviewed and approved numbered papers presented at General and District meetings and conferences. The publications are on an annual subscription basis. In consideration of payment of dues, members (exclusive of Student members) may receive one of the three publications; additional publications are offered to members at an annual subscription price of $2.50 each. Nonmembers may subscribe on an advance annual subscription basis of $5.00 each (plus 50 cents for foreign postage payable in advance in New York exchange). Single copies, when available, are $1.00 each. Discounts are allowed to libraries, publishers, and subscription agencies.

from the West Coast Subcommittee has been formed to prepare a report on West Coast practices for transil oil handling in substations.

An interim report was presented at the Summer and Pacific General Meeting in San Francisco by the Working Group on Extra High Voltage Substations. The work of this group will be continued and the final report will be presented at a future General Meeting.

Liaison representatives from this Committee have been assigned to working groups under the Committee on Transmission and Distribution, Committee on Telemetering, and the Standards Committee.

# AIEE FELLOWS ELECTED

**Board of Directors Meeting, August 17, 1956**

**Luigi Pancrazio Emanueli** (M '28, Life Member), vice-chairman of the Board of Directors and consulting engineer, Pirelli S. P. A., Milan, Italy, has been transferred to the grade of Fellow in the AIEE "...for the outstanding development of oil-filled cable which made practical underground power transmission at extra high voltages." Mr. Emanueli was born in Milan, Italy, May 4, 1883. He graduated from Politecnico di Milano with the degree of doctor of electrical engineering in 1906. He joined Pirelli S. P. A. in 1907 as a research engineer in the cable department, becoming technical manager of the department in 1917, and chief electrician in 1919. In that same year, he was made chief engineer of Pirelli–General Cable Works, Southampton, England. In 1931, he was appointed assistant vice-president, and in 1938 vice-president in charge of manufacturing, development, and research, Pirelli S. P. A., Milan. At the same time, he became a director of the board of Pirelli S. P. A. and also a director of Pirelli–General Cable Works. He was made general manager responsible for development and research in 1944, and assumed his present position as vice-chairman of the board of directors and consulting engineer in 1954. Mr. Emanueli's principal contribution is the development of the "Pirelli oil-filled cable," the first practical extra high voltage cable for which he is known the world over. This development made possible the transfer of large blocks of power through underground cables in congested areas. Mr. Emanueli is a member of Associazione Elettrotecnica Italiana, Institution of Electrical Engineers, Istituto Lombardo di Scienze e Lettere, and Societe Francaise des Electriciens. He is vice-president of International Conference on Large Electric High-Tension Systems (CIGRE).

**Arthur Eugene Fitzgerald*** (AM '31, M '39), electrical engineer, Jackson and Moreland, Boston, Mass., has been transferred to the grade of Fellow in the AIEE "...for his contributions to the teaching of electrical engineering and to the analysis of electric power system stability and operation." Dr. Fitzgerald was born in Brooklyn, N. Y., September 22, 1909. He graduated from the Polytechnic Institute of Brooklyn with the degree of electrical engineer in 1929. For the following two years he participated in a co-operative program involving test engineering work for the General Electric Company at Lynn, Mass., and study at the Massachusetts Institute of Technology, (MIT), resulting in the degree of master of science in electrical engineering from MIT in 1931. He was also granted the degree of doctor of science in electrical engineering by MIT in 1937. Dr. Fitzgerald joined the staff of MIT in 1931 as a research assistant, advancing to instructor in 1935, assistant professor in 1940, associate professor in 1945, and professor in 1952. He was responsible for the re-evaluation and development of electrical engineering courses for students not majoring in electrical engineering. In connection with this program he wrote the book "Basic Electrical Engineering," used in over 100 engineering schools in this country and abroad. He was also responsible for the development of a modern undergraduate course in electrical machinery for electrical engineering majors. He is coauthor of the book "Electrical Machinery," used in more than 50 engineering schools. Dr. Fitzgerald directed the use of the MIT network analyzer, and supervised graduate study in power system analysis. During his years at MIT, he served as a frequent consultant to Jackson and Moreland on matters of power system analysis and planning, and in 1954, he joined this consulting engineering firm on a full-time basis. At Jackson and Moreland he has carried out analysis of many utility and industrial electric power systems. Dr. Fitzgerald is a registered professional engineer in the State of Massachusetts. He is a member of Sigma Xi.

* Mr. Fitzgerald's transfer to the grade of Fellow was approved by the Board of Directors at their meeting on June 29, 1956.

**Oaklee Edgar Charlton** (AM '26, M '38), planning engineer, Southern Services, Inc., Birmingham, Ala., has been transferred to the grade of Fellow in the AIEE "...for his engineering achievements in the planning of a large interconnected power system." Mr. Charlton was born in Christiansburg, Va., October 19, 1897. He received a bachelor of science degree in electrical engineering from the Massachusetts Institute of Technology (MIT) in 1924. After graduation he joined the Dixie Construction Company, leaving in 1925 to become a graduate student and assistant in the Electrical Research Laboratory at MIT. In 1926, he returned to the Dixie Construction Company where he prepared studies and economic analyses of interconnected power companies. From 1930 to 1931, he was with Allied Engineers, Inc. (successors to Dixie Construction Company), as sponsor engineer for associated Mississippi Power and Gulf Power Companies. He also conducted general engineering and economic investigations of the Commonwealth and Southern interconnected system. From 1931 to 1949, with Commonwealth and Southern Corporation (successors to Allied Engineers, Inc.), he served as sponsor engineer for associated operating companies, co-ordinating engineering and economic studies between management, engineering, and operating departments. Mr. Charlton has been associated with Southern Services, Inc. (successors to Commonwealth and Southern Corporation), from 1949 to the present time, as system planning engineer for the Southern Company and its operating companies: Alabama Power, Georgia Power, Gulf Power, and Mississippi Power Companies. His responsibilities include direction of power supply studies, system design, equipment application, coordination of interconnected transmission systems, and general technical studies. His planning responsibilities embrace long-range programs for expanding operations of the Southern System, involving investigation of energy sources, analyses of plant sites, development of higher voltage transmission systems, and long-range economic studies. Mr. Charlton is a registered professional engineer in the State of Alabama. He has served on the following AIEE Committees: Protective Devices (1940–47), and System Engineering (1949–56).

**Arthur Frederick Hartung** (AM '28, M '35), partner, Burns and McDonnell Engineering Company, Kansas City, Mo., has been transferred to the grade of Fellow in the AIEE "...for his contributions to the design and development of electric power systems." Mr. Hartung was born in Kansas City, Mo., January 17, 1905. He received a bachelor of science degree in electrical

O. E. Charlton

L. P. Emanueli

A. E. Fitzgerald

*Courtesy Zitso Studio*

*Leo Stern, Photographer*

A. F. Hartung | M. E. Laborde | E. W. Logan | M. W. Smith | E. C. Wentz

engineering from the University of Kansas in 1926. After graduation, he spent three years with the General Electric Company in the testing department and as staff engineer in the switchgear engineering department. He was also selected to take the General Electric Company's advanced course in engineering. In 1929, Mr. Hartung joined the Burns and McDonnell Engineering Company as an assistant engineer. He became associate engineer in 1941, and partner of the firm in 1947. During his career with Burns and McDonnell, he has prepared many reports, studies, and designs for electrical and mechanical projects. He has been in charge of the design, construction, and supervision of numerous power stations and plants, and was directly responsible for high voltage transmission line projects for the Kansas City, Kans., Board of Public Utilities; City Utilities of Springfield, Mo.; Alabama Electric Co-operative, and others. The design and construction of utilities services including steam, compressed air, electric, and air conditioning for a number of large industrial plants and for the Atomic Energy Commission were also under his direction. Mr. Hartung is the author of numerous papers and articles on power plant and electrical subjects. He is a member of the American Society of Mechanical Engineers, National Society of Professional Engineers, Engineers Club of Kansas City, and Tau Beta Pi. He is a registered professional engineer in the States of Missouri, Florida, Illinois, Texas, and Utah. Mr. Hartung has served on the AIEE Committee on Power Generation (1949–50).

**Maurice Ernest Laborde** (M '48), assistant manager of the studies and research department, Electricité de France, Paris, France, has been transferred to the grade of Fellow in the AIEE "... for his contributions in the development and application of extra high voltage cables to underground power transmission." Mr. Laborde was born in Constantine, Algeria, August 17, 1900. He received the engineer's diploma from the Ecole Superieure d'Electricité in 1927. From 1927 to 1928, he was a probationary engineer at the Société Nord-Lumiere. Following this, he joined Union d'Electricité as an engineer in the electrical department. He became chief engineer in 1933, and assistant manager in charge of the studies and work department in 1941. In 1946, he went to Electricité de France as an engineer appointed to the direction of the studies and research department. From 1946 to 1950, as chief of the research services on system equipment, he was entrusted in particular with the study and installation of the Research and Testing Center of Fontenay, the most important laboratory for the testing of extra high voltage system equipment in France. Since 1950, he has been assistant manager of the studies and research department. In this position, he has carried out research on interruption phenomena and the development of extra high voltage insulated cables and submarine power cables. Mr. Laborde has had engineering experience in teaching as well as in industry. Since 1934, he has been master-lecturer and professor in charge of the course in power station and substation electrical equipment at the Ecole Superieure d'Electricité. He has been a member of the Board of Directors of the Ecole Superieure d'Electricité since 1939, and vice-president of the Board of Directors of the Society to promote the development of high grade teaching of electrical engineering in France since 1946. Mr. Laborde is a member of the French Electrotechnic Committee and has been French delegate at the International Electrotechnical Commission since 1939. He is a permanent member of the Conference Internationale des Grands Reseaux Electriques. He is also a member of Societe Francaise des Electriciens, Societe des Ingenieurs Civils de France, Union des Physiciens, Association Suisse des Electriciens, and Institution of Electrical Engineers. Since 1948, he has been chairman of the Board of Directors of the *Revue Générale d'Electricité*.

**Edwin William Logan** (AM '38, M '44), chief electronics engineer, The Emerson Electric Manufacturing Company, St. Louis, Mo., has been transferred to the grade of Fellow in the AIEE "... for his contributions to the development of automatic equipment for the direction of military weapons." Mr. Logan was born in Monroe, La., April 21, 1912. He received a bachelor of science degree in electrical engineering in 1937 from the Missouri School of Mines and Metallurgy. He also engaged in graduate studies in mathematics, mechanics, and servomechanisms at the Institute of Technology, St. Louis University. After graduation in 1937, Mr. Logan joined The Emerson Electric Manufacturing Company as commercial engineer. From 1939 to 1941, he served as chief research engineer, directing all phases of the research activities of the company. He was appointed chief electrical engineer of the newly formed Turret Division in 1942. In this capacity, he directed the design, development, installation, and test of the electrical control systems used in the aircraft gun turrets produced by the company. In co-operation with the Massachusetts Institute of Technology (MIT) Radiation Laboratory, he directed the installation of early radar and gun laying equipment in Emerson turrets and helped in their tests. Early in 1945, Mr. Logan was assigned the task of initiating the development of a radically new type of air-to-air automatic fire control system. He spent considerable time at the MIT Instrumentation Laboratory learning the philosophy of the new system and devoted further time at the MIT Servomechanisms Laboratory learning new control techniques. In 1948, Mr. Logan was made chief electronics engineer in the Electronic Development Engineering Division which Emerson established at that time. As chief of this division, he directs the technical design, development, and test of all electronic instrumentation, electronic computers, instrument and control system servos, radars, radar fuzes, vibration isolators, heat transfer units, system engineering philosophies, and electronic packages. Mr. Logan is a member of Tau Beta Pi, Phi Kappa Phi, Theta Tau, and Eta Kappa Nu. He is a registered professional engineer in the State of Missouri.

**Malcolm Winston Smith** (M '44), in charge of production and transmission construction, Ohio Edison Company, Akron, Ohio, has been transferred to the grade of Fellow in the AIEE "...for his contributions to the economical construction of transmission and generation facilities of a large electric power system." Mr. Smith was born in Steubenville, Ohio, May 30, 1899. He received a bachelor of science degree in electrical engineering from Pennsylvania State University in 1922. Mr. Smith has been associated with Ohio Edison and predecessor companies for 30 years. Following graduation in 1922, he did construction and maintenance work for the Carnegie Steel Corporation. In 1924 and 1925, he was engaged successively as electrician's helper, electrician, and electrical foreman on the building of the Toronto, Ohio, steam-electric generating station by Stevens and Wood, Inc., for the Ohio River Edison Company (a predecessor of the Ohio Edison Company). Following the completion of the Toronto plant, he served as its chief electrician for 10 years. From 1930 to 1936, he served on the Toronto, Ohio, City Council as president pro-tem

and chairman of the ordinance and finance committees. Following the Ohio River flood of March 1936, when the Toronto Station was flooded out, he developed the "low frequency" method of mass dry-out of motors and other electrical equipment. In 1937, he became superintendent of electrical construction for the company, with headquarters in Akron, in charge of all electrical station and substation construction and maintenance for the production and transmission department. He also co-ordinated the engineering of new projects and improvements. In 1947, he became general superintendent of production and transmission construction for the company, since which time he has supervised the installation of all new generation, transmission, substation, and steam heat station facilities for the company. On October 1, 1952, he was placed in charge of all production and transmission construction. Mr. Smith is a member of the Ohio Professional Engineers.

**Edward Charles Wentz** (AM '28, M '42), section manager, Westinghouse Electric Corporation, Sharon, Pa., has been transferred to the grade of Fellow in the AIEE "...for his design advances on high-capacity current transformers." Mr. Wentz was born in St. Paul, Minn., July 3, 1905. He received a bachelor of science degree in electrical engineering from the University of Minnesota in 1926 and a master's degree in electrical engineering from the University of Pittsburgh in 1936. In 1939, he received the electrical engineer's degree from the University of Minnesota. Following graduation in 1926, Mr. Wentz spent two years in a student course sponsored by Westinghouse. From 1928 to 1942, he was a design engineer in the instrument transformer section of the Westinghouse transformer engineering department. During these years, Mr. Wentz was responsible for development of a theoretical basis for the design of large current transformers for buss differential protection of large generator installations where the initial effect transient may tend to saturate the core and give false operation of relays. His work in this field led the industry in its applications for a number of years. From 1942 to 1952, Mr. Wentz served as acting section manager and section manager of the instrument transformer design section. From 1952 to the present time, he has been section manager in charge of a group of development engineers and has been responsible for the development of large power transformers including insulation, thermal design, and auxiliary equipment. In this connection, Mr. Wentz has contributed materially to the recent standardization of power transformer bushings to permit interchangeability among manufacturers. Mr. Wentz is the author of several technical papers which have appeared in AIEE *Transactions*. He has served on the following AIEE Committees: Relays (1947–49), and Transformers (1947–48).

# AIEE PERSONALITIES

**F. R. Kappel** (M '43, F '50), president, Western Electric Company, has been elected president of the American Telephone and Telegraph Company. Mr. Kappel was born in Albert Lea, Minn., January, 14, 1902. He was graduated from the University of Minnesota in 1924 with a bachelor of science degree in electrical engineering. He entered the Bell System in 1924 as a groundman with the Northwestern Bell Telephone Company and, thereafter, held a number of engineering and operating positions. He was elected a vice-president and director of Northwestern Bell in 1942. In 1949, Mr. Kappel went to American Telephone and Telegraph Company. That same year he was elected vice-president and placed in charge of the long lines department. He later became vice-president of the company in charge of operation and engineering. In 1954, he was named president of the Western Electric Company where he has been in charge of the manufacturing unit of the Bell System. Mr. Kappel received the University of Minnesota "Outstanding Achievement Award" in 1954. He is a member of Eta Kappa Nu.

F. R. Kappel

**P. A. Abetti** (AM '49, M '55), engineer in charge of the Computer Project, power transformer department, General Electric Company (GE), Pittsfield, Mass., has been awarded first prize in an international competition for the best original work on the subject of scientific advancement in technical applications of electricity in all fields. The award of $600 is being made to Dr. Abetti this fall by the Foundation George Montefiore in Belgium. The subject of his paper was the study of transient phenomena by means of electromagnetic models. Born in Florence, Italy, Dr. Abetti received the degree of doctor of engineering in 1945 from the University of Pisa. He came to the United States the following year and continued his studies at the Illinois Institute of Technology where he received a master of science degree in 1948 and the degree of doctor of philosophy in electrical engineering in 1953. In 1948, he joined the General Electric Company. Dr. Abetti received the Coffin Award from GE in 1953 for his work in electromagnetic models of power transformers. A member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi, he served on AIEE Basic Sciences Committee (1953–56).

**L. M. Goldsmith** (M '26, F '47), general manager, engineering and construction department, The Atlantic Refining Company, Philadelphia, Pa., has been honored for the completion of 40 years of service with the company. Dr. Goldsmith is well known for his many engineering contributions to the advancement of the petroleum industry. He successfully pioneered application of electric welding in construction of pipelines and ocean-going tankers. He engineered development of the first high-pressure, high-temperature, turbine electric steamship, and was later responsible for the world's first class of 30,000 deadweight ton supertankers used in the oil industry. During World War II, he served as an expert consultant to the War Department and was loaned to the British Ministry of War to participate in the development of their project PLUTO, by which flexible pipelines were successfully extended across the English Channel to supply petroleum products to Allied forces in France. Dr. Goldsmith at present is doing consulting work for the U. S. Army Transportation Corps. Dr. Goldsmith has served on the following AIEE Committees: Marine Transportation (1941–56), Chemical, Electrochemical, and Electrothermal Applications (1947–51), and Petroleum Industry (1954–56).

## OBITUARIES

**Nicholas John Conrad** (AM '07, F '21, Member for Life), former chairman of the board of S and C Electric Company, died recently in Evanston, Ill. He was 73 years old. Born March 21, 1883, in Port Washington, Wis., he graduated from the University of Wisconsin in 1905 with a degree in electrical engineering. His initial professional position was with the Commonwealth Edison Company as a testing engineer. In 1910, Mr. Conrad and E. O. Schweitzer, also with Commonwealth Edison Company, organized their own company, Schweitzer and Conrad, Inc., to manufacture a new high voltage fuse which they had jointly invented. A few years later, Mr. Conrad left Commonwealth Edison to devote his entire time to the management of the new company. In 1945, he acquired sole control of the company, and at that time the name was changed to S and C Electric Company. During World War II, Mr. Conrad was chairman of The Chicago Advertising Commission of Naval Officer Procurement for one year, as well as Chicago district manager of the War Production Board in 1943, and a member of the Selective Service Cook County Appeal Board from 1943 to 1947.

**John Forbes Nash** (AM '17, M '26), system supervising distribution engineer of Appalachian Electric Power Company, died recently. He was 64 years old. Mr. Nash was born February 18, 1892, in Bonham, Tex. He was a graduate of Texas A and M

College where he received his bachelor of science degree in electrical engineering. After graduation, he worked a year for the Texas Power and Light Company before going to Schenectady, N. Y., to take General Electric student engineer training. After serving as a supply officer with the infantry in Europe during World War I, he returned to General Electric and then became an assistant professor of electrical engineering at Texas A and M. An employee of Appalachian for more than 36 years, he joined the company as an engineer in Bluefield, W. Va. on June 1, 1920. All of his service was spent in the Bluefield Division until 1952, when he was promoted to system supervising distribution engineer, with his office in Roanoke, Va. He was a member of the West Virginia Society of Professional Engineers and a registered professional engineer of that State.

**Harry Paul Dupuis** (AM '41, M '49), electrical engineer, Commonwealth Associates, Inc., Jackson, Mich., died recently at the age of 61. Mr. Dupuis graduated from the University of Wisconsin in 1925 with a degree in electrical engineering. He had been employed by Commonwealth Associates, Inc., and predecessor companies since 1927. He was best known for his work in fault location along transmission lines. Mr. Dupuis was the author of several papers presented before the AIEE.

# MEMBERSHIP

## Recommended for Transfer

The Board of Examiners at its meeting of September 20, 1956, recommended the following applications for transfer. Any objections to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

### To Grade of Member

Acton, W. S., general engineer, Bonneville Power Administration, Portland, Ore.
Alexander, J. G., engineer, T&P group, Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Allerton, G. L., electrical engineer, Western Electric Co., Allentown, Pa.
Anderson, P. M., instructor, electrical engineering dept., Iowa State College, Ames, Iowa.
Angell, J. R., staff electrical engineer, Kaiser Aluminum & Chemical Corp., Oakland, Calif.
Applegate, C. E., Arthur D. Little, Inc., 30 Memorial Dr., Cambridge 42, Mass.
Aronson, H. A., development engineer, Motorola, Inc., Chicago, Ill.
Askew, W. H., electrical engineer, National Bureau of Standards, Washington, D. C.
Bailey, P. L., district superintendent, Appalachian Electric Power Co., Lynchburg, Va.
Baines, R. W., communication engineer, Texas Eastern Transmission Corp., Shreveport, La.
Baker, R. R., fellow engineer, Westinghouse Electric Corp., East Pittsburgh, Pa.
Baldwin, J. N., meter engineer, Commonwealth Edison Co., Chicago, Ill.
Ballard, E. J., Jr., assistant professor, University of Nebraska, Lincoln, Nebr.
Barnhart, H. D., measurements engineer, General Electric Co., Erie, Pa.
Beck, A. W., electrical superintendent, northwestern mining dept., American Smelting & Refining Co., Wallace, Idaho.
Belding, M. D., manager, Westinghouse Electric Corp., Knoxville, Tenn.
Berry, J. J., electrical engineer, U. S. Army Corps of Engineers, Jacksonville, Fla.
Biggers, B., power sales engineer, Southwestern Public Service Co., Borger, Tex.
Biggs, F. I., engineering manager, Ridgway Div., Elliott Co., Ridgway, Pa.
Blaicher, H. E., Jr., district planning engineer, Jersey Central Power & Light Co., Asbury Park, N. J.
Bosshart, W. R., electrical engineer, Bonneville Power Administration, Portland, Ore.
Brown, J. S., director of engineering, Andrew Corp., Chicago, Ill.
Burke, S. M. S., senior distribution engineer, Alabama Power Co., Birmingham, Ala.
Burnett, K. H., project engineer, F. W. Sickles Div., General Instrument Corp., Chicopee, Mass.
Carruth, H. B., distribution engineer, Southwestern Gas & Electric Co., DeQueen, Ark.
Carter, R. C., Jr., electrical engineer, USAF, Arnold Engineering Development Center, Tenn.
Cassard, H. D., Jr., assistant engineer, Baltimore Gas & Electric Co., Baltimore, Md.
Chapman, A. G., consultant, Rural Electrification Administration, Washington, D. C.
Chen, K., equipment engineer, Lamp Div., Westinghouse Electric Corp., Bloomfield, N. J.
Cheshire, W. E., assistant engineer, The Cincinnati Gas & Electric Co., Cincinnati, Ohio.
Cooper, B., manager design engineering, General Electric Co., Waynesboro, Va.
Cummins, W. A., supervising engineer, Southwestern Public Service Co., Amarillo, Tex.
Cunningham, F. V., engineer, Line Material Co., South Milwaukee, Wis.
Damidovich, J. F., staff assistant, Commonwealth Edison Co., Chicago, Ill.
Davis, C. E., partner, Davis & Robinson, consulting engineer, Oklahoma City, Okla.
DeWolf, F. T., supervisor electromechanical unit, General Electric Co., Erie, Pa.
Diebold, E. J., chief engineer, germanium power rectifier, International Rectifier Corp., El Segundo Calif.
Dunfee, B. L. (Mrs.), physicist, National Bureau of Standards, Washington, D. C.
Dvorak, W. F., engineering & estimating, Federal Pacific Electric Co., Cleveland, Ohio.
Edwards, L. M., assistant general engineer, Savannah Electric & Power Co., Savannah, Ga.
Eidell, R. H., experimental engineer, Bethlehem Steel Co., Bethlehem, Pa.
Epstein, H., department manager, Burroughs Corp., Paoli, Pa.
Feldt, B. F., engineer, Air Arm Div., Westinghouse Electric Corp., Baltimore, Md.
Fry, T. R., chief engineer, Porcelain Products, Inc., Parkersburg, W. Va.
Fyhrie, G., electrical engineer, Fairchild AFB, Fairchild, Wash.
Gade, D. W., senior research engineer, Autonetics Div. of North American Aviation, Downey, Calif.
Gardner, K. G., specialist, I&S engineering, General Electric Co., Amarillo, Tex.
Goetz, G. A., general foreman electrical operations, U. S. Steel Corp., Fairless Hills, Pa.
Gomulkiewicz, P. H., electrical engineer, Aluminum Co. of America, Vancouver, Wash.
Goodroe, C. R., electrical engineer, Tennessee Valley Authority, Chattanooga, Tenn.
Gore, W. C., assistant professor of electrical engineering, The Johns Hopkins University, Baltimore, Md.
Grasser, W. E., senior engineer, Liebel Flarsheim Co., Cincinnati, Ohio.
Hamilton, L. F., engineer, Philadelphia Electric Co., Philadelphia, Pa.
Hammann, J. W., lecturer in electrical engineering, Washington University, St. Louis, Mo.
Hanlon, J. F., assistant manager, Washington D. C. Office, Westinghouse Electric Corp., Washington, D. C.
Hartshorn, J. A., apparatus engineer, Line Material Co., Revere, Mass.
Hayes, H. M., sales engineer, General Electric Co., Albuquerque, N. M.
Heard, J. T., Jr., senior design engineer, McDonell Aircraft Corp., St. Louis, Mo.
Heffron, W. G., Jr., senior dynamics engineer, Convair Div., General Dynamics Corp., San Diego, Calif.
Hoffman, F. W., Jr., senior voltage control engineer, Pennsylvania Power & Light Co., Hazleton, Pa.
Hudson, J. A., electrical engineer, Lowell Electric Light Corp., Lowell, Mass.
Ilyas, S. M., senior reader & head electrical engineering dept., University of Peshawar, Pakistan.
Jatras, S. J., chief engineer, Midwestern Instruments, Tulsa, Okla.
Jeffs, T. W., senior engineer, General Electric Co., Richland, Wash.
Jones, R. E., supervisor, inspection & test unit, General Electric Co., Erie, Pa.
Kagan, C. A. R., engineer, Western Electric Co., Lawrence, Mass.
Keene, L. M., electrical engineer, General Electric Co., Richland, Wash.
Keller, I. W., division operating superintendent, N. Y. State Electric & Gas Corp., Elmira, N. Y.
Kelley, W. J., assistant to vice-president, Illinois Power Co., Decatur, Ill.
Kennel, B. W., chief electrical engineer, Eicor, Inc., Oglesby, Ill.
Klein, K. M., engineering program co-ordinator, Bonneville Power Administration, Portland, Ore.
Koeppel, B. W., senior research engineer, Seismograph Service Corp., Tulsa, Okla.
Koller, R., director, MICAFIL, S. A., Zurich, Switzerland.
Korn, H., Jr., project engineer, Motorola, Inc, Chicago, Ill.
Kristensen, M. H., 504 David Court, Cheyenne, Wyo.
Landes, I. H., engineer, Commonwealth Associates, Inc., Jackson, Mich.
Leibold, C. A., vice-president & electrical engineer, Berks Engineering Co., Reading, Pa.
Leimkuhler, E. J., engineer, Baltimore Gas & Electric Co., Baltimore, Md.
MacDonald, J. W., estimate engineer, Procon Inc., DesPlaines, Ill.
MacLuckie, W. A., electrical engineer, J. J. Henry Co., Inc., Philadelphia, Pa.
Maenpaa, W. K., head, electronic packaging, General Railway Signal Co., Rochester, N. Y.
Mathias, G. E., design engineer, Westinghouse Electric Corp., Buffalo, N. Y.
Meadows, J. P., meter superintendent, Southwestern Gas & Electric Co., Marshall, Tex.
Medal, E. C., engineer, Commonwealth Edison Co., Chicago, Ill.
Mitropoulos, T. N., head, electrical laboratory, Simplex Wire & Cable Co., Cambridge, Mass.
Moody, J. E., industrial engineer, Southwestern Gas & Electric Co., Shreveport, La.
Petersen, D. P., chief engineer, Allen D. Cardwell Electronics Production Corp., Plainville, Conn.
Posey, R. P., application engineer, Honolulu Electrical Products Co., Ltd., Honolulu, T. H.
Quinlan, R. E., staff engineer, Sandia Corp., Albuquerque, N. M.
Rasmussen, A. P., manager, control equipment engineering, Westinghouse Electric Corp., Baltimore, Md.
Reynolds, D. J., electronic engineer, Westinghouse Electric Corp., Chicago, Ill.
Rottman, W. J., electronics engineer, Goodyear Aircraft Corp., Akron, Ohio.
Russo, H. L., project engineer, Duquesne Light Co., Pittsburgh, Pa.
Saverino, E. V., electrical senior designer, Chemical Construction Corp., New York, N. Y.
Schreiner, W. H., manager, Aiken Electric Cooperative Inc., Aiken, S. C.
Shipley, C. S., electrical engineer, Tennessee Valley Authority, Chattanooga, Tenn.
Slader, G. Y., system planning engineer, Gatineau Power Co., Hull, Que., Can.
Slagter, H. C., engineer, naval ordnance dept., General Electric Co., Pittsfield, Mass.
Slevin, J. J. manager Illuminating Div. The Miller Co. New York, N. Y.
Smith, G. E., assistant professor of electrical engineering, University of Kentucky, Lexington, Ky.
Spain, W. M., regional manager, Federal Pacific Electric Co., Chicago, Ill.
Springer, J. J., supervisor, electric operations analysis dept., Public Service Co. of Colorado, Denver, Colo.
Stivers, W. C., senior engineer, Bechtel Corp., San Francisco, Calif.
Strelesky, H. J., equipment & bldg. engineer, Mountain States Tel. & Tel. Co., Helena, Mont.
Strout, F. H., assistant to vice-president, Northern Indiana Public Service Co., Hammond, Ind.
Suter, S. G., design engineer, Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Sweeney, P. M., engineer, Pacific Tel. & Tel. Co., Portland, Ore.
Taylor, R., electrical engineer, Consumers Power Co., Jackson, Mich.
Toomer, F. S., assistant division superintendent, Alabama Power Co., Birmingham, Ala.
Wahl, R. E., technical unit leader, General Electric Co., Lynn, Mass.
Wendt, R. E., Jr., senior engineer, Westinghouse Electric Corp., Pittsburgh, Pa.
White, D. C., associate professor of electrical engineering, Massachusetts Institute of Technology, Cambridge, Mass.
Williams, W. L., Jr., construction manager, Harry F. Ortlip Co., Philadelphia, Pa.
Winter, P. H., physicist, Mine Fuze Div., Diamond Ordnance Fuze Laboratories, Washington, D. C.
Woll, R. A., electrical engineer, Vern E. Alden, Engineers, Chicago, Ill.
Youngblood, J., supervising engineer, Detroit Edison Co., Detroit, Mich.
Zander, F. W., Jr., division engineer, Florida Power Corp., Ocala, Fla.

117 to grade of Member

## Applications for Election

Applications for admission or re-election to Institute membership in the grade of Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before November 25, 1956 or January 25, 1957, if the applicant resides outside of the United States, Canada or Mexico.

### To Grade of Member

Allan, J. C., product design & production engineer, Canadian General Electric Co., Ltd., Peterborough, Ontario, Canada.
Balkow, E. C., engineer, Pacific Telephone & Telegraph Co., San Francisco, Calif.
Brodie, P. K., district engineer, South of Scotland Electricity Board, Cupar, Fife, Scotland.
Cockrell, J. L., research engineer, Leeds & Northrup Co., Philadelphia, Pa.
Cypers, K. L., supervising engineer, General Electric Co., Newark, N. J.
Harper, H. W., chief engineer, Northeastern Steel Corp., Bridgeport, Conn.
Heath, E. H., chief electrical engineer, Master Electric Co., Dayton, Ohio.
Lorimer, J. L., electrical engineer, West Virginia Pulp & Paper Co., Charleston, S. C.
Popescu, E. P., electrical designer, J. G. White Corp., New York, N. Y.
Robinson, P., director consultant, Sprague Electric Co., North Adams, Mass.
Sigley, D. T., chief engineer, Firestone Tire & Rubber Co., Los Angeles, Calif.
Van Zandt, L. M., South Texas representative, RT&E Corp. of Waukesha, Wis., San Antonio, Tex.

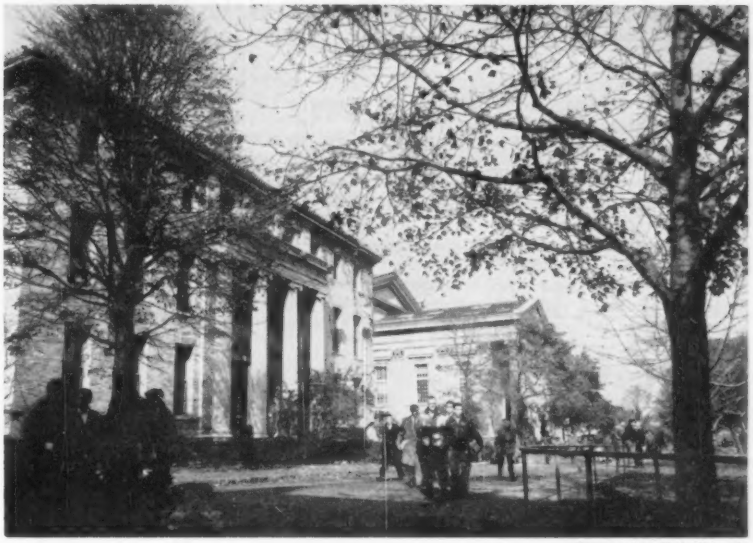
12 to grade of Member

ELECTRICAL ENGINEERING EDUCATION

## AIEE in New York University

THE COLLEGE OF ENGINEERING of New York University is one of the oldest and largest in the United States. Actual instruction in engineering began in September 1855 and the first undergraduate degree was awarded in June 1857. The first outstanding accomplishment in the field of electrical engineering at the University was performed by Prof. Samuel F. B. Morse, while a member of the faculty in 1835, with his invention "The Recording Electric Telegraph."

The Day Division student branch of AIEE at New York University was organized December 5, 1924. A few years later a separate Evening Division student branch was established. For the past two consecutive years, 1955–56, New York University students have won the First Prize in the District No. 3 Student Prize Paper Contest as well as winning the 1955 Second Prize in the AIEE National Student Prize Paper Contest.



*Courtesy New York University*

# Compact Operational Amplifier Designed for a Table Model Computer

W. F. OSBORN
STUDENT MEMBER AIEE

THE MANY PROBLEMS that are often encountered in the fields of engineering and science are generally approached by the method of expressing the problem by mathematical symbols and equations. By applying mathematical methods that are governed by proved theorems, it is possible to obtain solutions to the majority of these equations without encountering very much difficulty; yet there are many equations, the solution of which require many hours of computation. There are also many equations which cannot be solved by the ordinary or advanced mathematical techniques known today.

Because the use of existing mathematical techniques either fail or become impractical for solving some of the equations encountered, other methods of approach have been devised. One of these methods is the employment of electronic devices commonly known as computers.

Text of paper awarded prize in District 7 Student Prize Paper Contest.

**W. F. Osborn** is a student at Texas Agriculture and Mining College, College Station, Tex.

It is the purpose of this report to familiarize the reader with the fundamentals of a computer, which was devised for solving differential equations, and to introduce a compact operational amplifier, which was designed to be used in a small table model computer. First, analogue computers, in general, will be discussed. In order to present to the reader the functioning of an analogue computer a discussion must be made concerning the primary circuits of a computer, how they are employed, and the techniques used in the handling of equations for their solution by means of computers. The scope of this article has been limited to a computer of the analogue type.

### Analogue Computers—General

The primary mission of an analogue computer is to solve differential equations. Thus, before beginning the discussion concerning the primary components of an analogue computer, it is advantageous to review certain mathematical relationships and also to determine the operations required of the components.

Of primary interest are differential equations, therefore, first a differential equation will be defined. A differential equation is said to be any equation that contains differentials or derivatives. For example

$$5x+2\frac{dx}{dt}+3\frac{d^2x}{dt^2}=0 \qquad (1)$$

is a differential equation. A differential equation may contain one or any number of derivatives; these derivatives may be of any order. That is, the derivatives may be either first, second, third order, etc. Equation 1 is an example of a second order differential equation.

By integrating twice, it can be shown that the solution to equation 1 is the same as the solution to equation 2, thus

$$5\int\int x dt+2\int x dt+3x=0 \qquad (2)$$

Assume it is required to solve equation 2 with an analogue computer. It is apparent that the computer must be capable of performing the operations of addition, multiplication, and integration. The analogue computer is just such a device. It is capable of performing the fundamental operations of addition, multiplication, differentiation, and integration, etc., of slowly varying voltages. These voltages vary with respect to time in the same fashion as a mathematical function varies with respect to the independent variable. The analogy which exists between the voltages in the machine and the mathematical functions was responsible for naming this type of computer an analogue computer. (A more desirable name would be "differential analyzer" or "integrating synthesizer.")

Before proceeding, it must be noted that the functions of the equations are represented in the computer by voltages. For

example, the equation $f(x)+g(x)$ can be represented in the computer by the voltages, $v(t)+w(t)$. Also, it must be noted that all voltages and currents referred to, hereafter, are dependent upon time; that is, $e$ and $i$ should be written either $e(t)$ or $i(t)$. In the following equations, the $(t)$ has been dropped for clarity.

The primary component of an analogue computer is a d-c amplifier, referred to as an operational amplifier. An operational amplifier, combined with different impedances, performs the operations of addition, multiplication by a constant, differentiation, and integration.

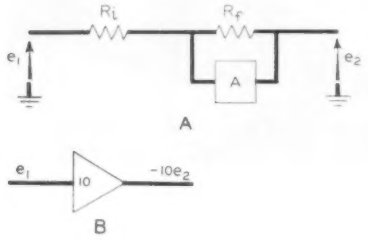



Fig. 1(A). Operational amplifier used to multiply a function by a constant. Fig. 1(B). Symbol.

The operation of differentiation will not be discussed, for when the operation of differentiation is performed by an operational amplifier many errors are introduced that normally render the solution unusable.

#### Amplifier Used to Multiply

The circuit of an operational amplifier used to multiply a function by a constant is given in Fig. 1(A), where $e_1$ is the input voltage and $e_2$ is the output voltage. $R_f$ and $R_i$ are pure resistances. $A$ is a d-c amplifier of gain $A$. The relationship between the input voltage $e_1$ and the output voltage $e_2$ is given to a very close approximation by equation 3.

$$e_2 = -\frac{R_f}{R_i} e_1 \tag{3}$$

The symbol indicating an operational amplifier used to multiply a function by a constant is given in Fig. 1(B). The number 10 contained within the symbol indicates the constant by which the applied input voltage is multiplied. For example, if a voltage equal to $f(x)$ were applied at the input, then a voltage equal to $-10f(x)$ would appear at the output. Note that the input voltage and the output voltage are 180 degrees out of phase. This is true, independent of the operation that is performed on the applied function, whether it be integrated, etc. In other words, when a function passes through an operational amplifier its sign is changed.

It is apparent from equation 3 that the multiplying constant is dependent upon the values of $R_f$ and $R_i$. For example, if a constant 10 is desired, then it is possible to obtain this value by making $R_f$ equal to 1 megohm and $R_i$ equal to 100,000 ohms.

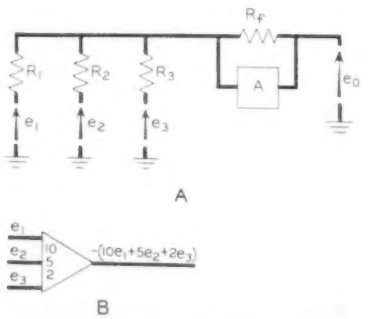



Fig. 2(A). Operational amplifier used as an "adder." Fig. 2(B). Symbol.

#### Amplifier as "Adder"

When an operational amplifier is used to add several voltages, it is referred to as an "adder." The circuit of an adder is given in Fig. 2(A), where $e_1$, $e_2$, and $e_3$ are the input voltages, and $e_0$ is the output voltage. $A$ is a d-c amplifier of gain $A$ and $R_1$, $R_2$, $R_3$, and $R_f$ are pure resistances. The relationship between the input voltages and the output voltage is given to a very close approximation by equation 4.

$$e_0 = -\left(\frac{R_f}{R_1} e_1 + \frac{R_f}{R_2} e_2 + \frac{R_f}{R_3} e_3\right) \tag{4}$$

The symbol used to indicate an adder is given in Fig. 2(B). The numbers 10, 5, and 2 contained within the symbol indicate the constants by which the applied voltages are multiplied. It can be observed from equation 4 that these constants are dependent upon the values of $R_1$, $R_2$, $R_3$, and $R_f$. If a voltage equal to the function $f_1(x)$ were applied to input number 1, etc., and if the constants are as indicated in Fig. 2(B), then the output voltage would equal $-10f_1(x)-5f_2(x)-2f_3(x)$. Any number of input voltages may be applied to an adder, but normally no more than five to seven input voltages are applied at any one time.

#### Amplifier Used as Integrator

When an operational amplifier is used to integrate a function it is referred to as an integrator. The circuit of an integrator is given in Fig. 3(A), where $e_1$ is the input voltage, $e_2$ is the output voltage, and $A$ is an amplifier of gain $A$. $R$ and $C$ are pure resistance and a pure capacitance, respectively. The relationship between the input and output voltages is given to a very close approximation by equation 5.

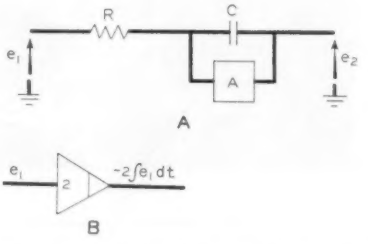



Fig. 3(A). Operational amplifier used as an integrator. Fig. 3(B). Symbol.

$$e_2 = -\frac{1}{Rc}\int e_1 dt \tag{5}$$

The symbol indicating an integrator is given in Fig. 3(B). As before, the number 2 included in the symbol indicates the multiplying constant. It is apparent from equation 5 that the multiplying constant is dependent upon $1/RC$. If a constant of 2 is desired, it may be obtained by making $R$ equal to 500,000 ohms, and $C$ equal to 1.0 microfarad.

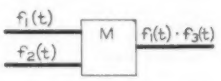



Fig. 4. Function multiplier symbol.

From equation 5, note that the input voltage is integrated with respect to time; therefore, all differential equations solved by analogue computers must be written with their derivatives varying with respect to time. For example, if asked to solve equation 6 using a computer, let $x=t$ and rewrite

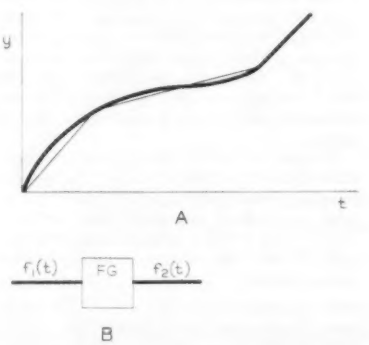



Fig. 5(A). Function generator output. Fig. 5(B). Schematic design.

the equation. Equation 7 is the new equation:

$$A\frac{d^2y}{dx^2}+B\frac{dy}{dx}+C=0 \tag{6}$$

$$A\frac{d^2y}{dt^2}+B\frac{dy}{dt}+C=0 \tag{7}$$

With the circuits previously mentioned it is impossible to multiply a function of time by another function of time. This is often necessary in solving differential equations. For example, to solve Bessel's equation

$$t^2\frac{d^2y}{dt^2}+t\frac{dy}{dt}+t^2y=0 \tag{8}$$

it is necessary to multiply the functions of time $t$ and $t^2$ by other function of time, mainly,

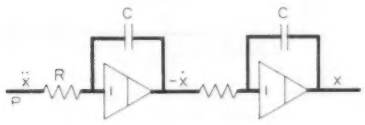



Fig. 6. Amplifier, showing output.

$d^2y/dt^2$, $dy/dt$, and $y$. Before this operation of multiplication can be performed, it is also necessary to generate the functions $t$ and $t^2$. Therefore, it is necessary to have components that will generate functions and multiply functions of time. The circuits used to perform these operations are too complex to be described in this article, therefore, only a short explanation of each will be included.

### Function Multipliers

A function multiplier is an electronic device capable of multiplying one function dependent upon time multiplied by another function dependent upon time. For example, a function multiplier would be employed in a computer to multiply $t^2$ times $d^2y/dt^2$ to obtain $t^2\ d^2y/dt^2$. Schematically, a function multiplier is indicated by the symbol in Fig. 4, where $f_1(t)$ is the function applied to input number one, $f_2(t)$ is the function applied to input number two, and $f_1(t)$ times $f_2(t)$ is the output. If $-f_1(t)$ were applied to input number one and $f_2(t)$ were applied to input number two, then $-f_1(t)f_2(t)$ would appear at the output. Many multipliers are designed so that the sign of the output may be chosen either negative or positive, independent of the signs of the inputs.

### Function Generators

A function generator is an electronic device, capable of producing an output voltage that is some desired function of time or of some other function. A very common type of function generator approximates a function by straight lines. This may be more clearly understood by reference to Fig. 5(A). The smooth continuous curve is the desired function; the series of short straight lines is the actual function generated. Thus, it can be seen that this type of function generated introduces a certain amount of error caused by the approximation.

Another limitation of many function generators is that the function produced must be either monotonic increasing or monotonic decreasing. That is, the function must either start at some minimum value and continually increase or, if the function is monotonic decreasing, it must start at some maximum value and continually decrease. Although function generators have certain limitations, almost all desired functions may be generated without encountering very much difficulty.

Schematically a function generator is represented as shown in Fig. 5(B). The output of a function generator may be either negative or positive, whichever is desired. Some of the more advanced multipliers are capable of generating some functions. The most common are exponential functions.

By employing the previously mentioned components, an analogue computer is capable of solving, in general, the most complicated differential equations. The types and

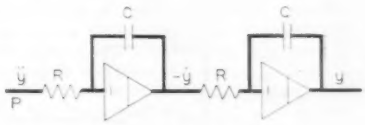



Fig. 9. Output of amplifier.

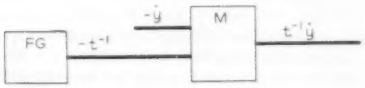



Fig. 10. Output of function generator and multiplier.

complexity of the equations that can be solved employing analogue computers is dependent upon the number of operational amplifiers available, the number of multipliers available, and the types of functions that need to be generated.

In the following discussion it will be assumed that there are sufficient operational amplifiers and multipliers available and, also, that any necessary functions may be generated. It will also be assumed that the sign of the output of the multipliers may be either negative or positive, as is desired.

### Techniques Applied

The procedure used to prepare a differential equation for solution by an analogue computer is: (1) write the equation with the derivatives or differentials varying with respect to time; (2) solve the equation for the highest order derivative; and (3) schematically represent the equation in computer language. Assume that the equation

$$10\frac{d^2x}{dt^2}-5\frac{dx}{dt}+x=0 \tag{9}$$

is to be solved employing an analogue computer, where $x(0)=A$ and $dx/dt(0)=B$ are the initial conditions. For simplicity, let

$$\frac{d^2x}{dt^2}=\ddot{x} \tag{10}$$

and

$$\frac{dx}{dt}=\dot{x} \tag{11}$$

Thus, equation 9 may be written

$$10\ddot{x}-5\dot{x}+x=0 \tag{12}$$

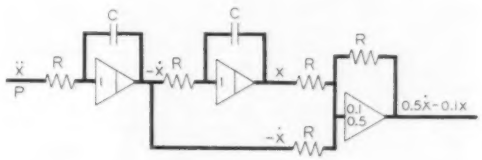



Fig. 7. Amplifier, showing output of "adder."

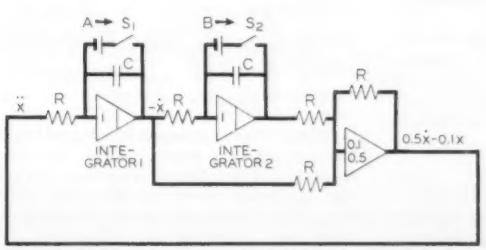



Fig. 8. Amplifier, showing output of integrators.

Now solve equation 12 for the highest order derivative, or

$$\ddot{x}=0.5\dot{x}-0.1x \tag{13}$$

If we assume that a voltage proportional to $\ddot{x}$ is present at some point $P$ in the machine, as shown in Fig. 6, then this voltage may be

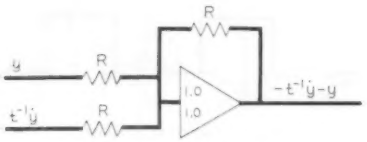



Fig. 11. Output of multiplier.

integrated once to obtain $-\dot{x}$ (change in sign always present) and twice to obtain $x$. If $x$ and $-\dot{x}$ are applied to an adder with the proper multiplying constants of 0.1 and 0.5, respectively, as shown in Fig. 7, the output of the adder would be $0.5\dot{x}-0.1x$, where again a change in sign accompanies the operation.

It is noticed that the output voltage of the adder is by equation 13 equal to $\ddot{x}$, therefore, we must satisfy the differential equation by connecting the output of the adder to point $P$, where $\ddot{x}$ was assumed to exist.

#### Initial Conditions

The initial conditions $\dot{x}(0)=A$ and $x(0)=B$ are forced into the circuit by charging the integrating capacitors at $t=0$, so that the voltages appearing at the outputs of integrators 1 and 2 are $B$ and $A$ volts, respectively. This is done by closing switches $S_1$ and $S_2$, shown in Fig. 8, momentarily. As soon as $S_1$ and $S_2$ are opened, the solution of the differential equation, with the proper initial conditions, will appear at the output of integrator 2. Inasmuch as this solution appears in the form of a voltage, it may be recorded on an oscillograph or viewed in an oscilloscope.

It is also noticed that the equation could be solved with different initial conditions by merely changing the voltages $A$ and $B$. By changing gains of the adder, the equation could be solved for different values of the coefficients of $\dot{x}$ and $x$. This property of easily changing initial conditions and coefficients make the analogue computer a very useful tool for exploratory work, such as optimizing or minimizing solutions by trial and error.

Because equation 9 is relatively easy to solve using ordinary mathematical techniques, a more complex equation will be discussed in order to show how functioning generators and multipliers are employed in analogue computers. Also, the true value of analogue computers will be better understood. Assume that Bessel's equation

$$t^2\frac{d^2y}{dt^2}+t\frac{dy}{dt}+t^2y=0 \tag{14}$$

is to be solved with the initial conditions of $dy/dt(0)=A$ and $y(0)=B$. Let

$$\frac{d^2y}{dt^2}=\ddot{y} \tag{15}$$

and

$$\frac{dy}{dt}=\dot{y} \tag{16}$$

Thus, equation 14 becomes

$$t^2\ddot{y}+t\dot{y}+t^2y=0 \tag{17}$$

Then, as before, solve the equation for the highest order derivative, thus:

$$\ddot{y}=-t^{-1}\dot{y}-y \tag{18}$$

If we assume that a voltage proportional to $\ddot{y}$ is present at some point $P$, as shown in Fig. 9, then this voltage may be integrated once to obtain $-\dot{y}$, and twice to obtain $y$. (Note the change in signs.) If a voltage equal to $-t^{-1}$ is now generated by a function generator and applied to one of the inputs of a multiplier, and the voltage equal to $-\dot{y}$ is applied to the other input of the multiplier, as is shown in Fig. 10, then a voltage equal to $t^{-1}\dot{y}$ will appear at the output of the multiplier. Now, if the voltage equal to $t^{-1}\dot{y}$ is applied to the other input of the adder, as shown in Fig. 11, and if both inputs have a gain of unity, then a voltage equal to $-t^{-1}\dot{y}-y$ will appear at the output of the adder. From equation 18, observe that $-t^{-1}\dot{y}-y$ equals $\ddot{y}$; therefore, the output voltage of the adder is applied to point $P$ where the voltage $\ddot{y}$ was assumed to exist. Thus, the differential equation is satisfied.

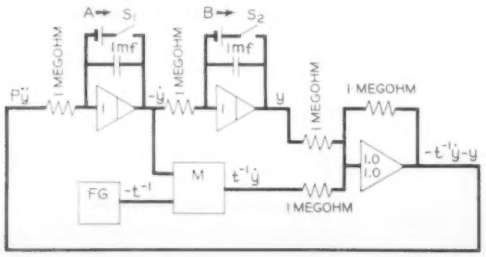



Fig. 12. Complete schematic diagram of amplifier.

A complete schematical representation of this circuit is given in Fig. 12.

The initial conditions may be satisfied by closing the switches, $S_1$ and $S_2$, shown in Fig. 12, momentarily. Inasmuch as $y$ is the solution to the differential equation, the voltage equal to $y$ may be recorded, as previously mentioned.

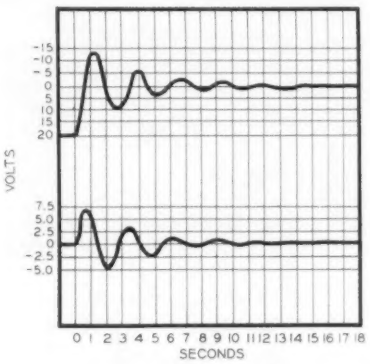



Fig. 13. Solution of the equation.

#### Evaluation of Results

To demonstrate the method used for evaluating results of a solution of a differential equation obtained from an analogue computer, the equation

$$\frac{d^2x}{dt^2}+0.52\frac{dx}{dt}+5.38x=0 \tag{19}$$

has been solved analytically and by an analogue computer. The analytical solution of equation 19, which was obtained employing the method of symbolic operators is

$$x=e^{-0.26t}(c_1\cos 2.3t+c_2\sin 2.3t) \tag{20}$$

where $C_1$ and $C_2$ are dependent upon the initial conditions. Equation 19 was solved by an analogue computer with the initial conditions of

$$\frac{dx}{dt}(0)=20 \text{ volts} \tag{21}$$

and

$$x(0)=0 \text{ volts} \tag{22}$$

Therefore, $C_1=8.8$, and by substitution, equation 20 becomes

$$x=e^{-0.26t}(8.8\sin 2.3t) \tag{23}$$

The solution of equation 19, obtained from the computer, is shown in Fig. 13. The lower plot is the solution to equation 19, and the upper plot is the first derivative of the solution. The evenly spaced marks at the lower edge of the figure are time marks of 1

second interval. The solution was plotted to a scale of 0.8 cm = 5 volts. The first derivative was plotted to a scale of 0.8 cm = 10 volts. The time marks are spaced 5 mm apart.

In order to show that the computer solution is the same as the analytical solution, notice that for $t = 0.68$ second, which is one fourth of the period, the computer solution gives 7.5 volts, and the analytical solution gives 7.4 volts. Several other analytical solutions correspond to computer results.

Now that the fundamentals of an analogue computer has been presented, a compact operational amplifier suitable for table model type computers will be presented.

### A Compact Operational Amplifier

In order to be used in a table model computer, an operational amplifier must be of relative small size, consume small quantities of power, and have a minimum of drift. The amplifier described herein is an amplifier that meets these requirements. Also, it is a very inexpensive amplifier.

The over-all size of the amplifier not including the filament transformer is approximately $3 \times 3\frac{1}{2} \times 4$ inches. It requires a maximum of 17.5 milliamperes, and a voltage supply of $\pm 300$ volts. The over-all circuit requires two miniature tubes, two 2-watt potentiometers, one 10-watt resistor, two 1-watt resistors, and three 1/2-watt resistors. The over-all cost, excluding the filament transformer, is approximately seven dollars.

The circuit of the amplifier is given in Fig. 14. The maximum output of this amplifier is approximately $\pm 62.5$ volts (peak to peak) without developing appreciable distortion. The drift over a period of a few minutes is negligible. The frequency response without feedback is excellent up to a frequency of 50,000 cps. The minimum load which may be applied to this amplifier is 15,000 ohms. The gain of the amplifier is approximately 2,500.

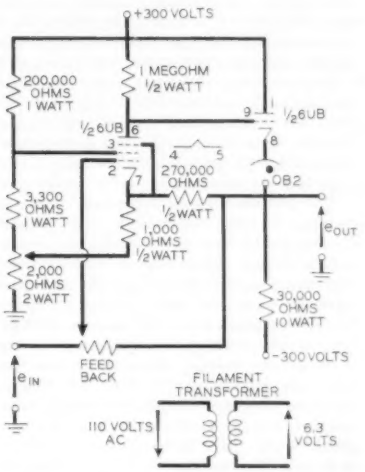



Fig. 14. Schematic of a compact operational amplifier.

It is the author's belief that this amplifier is excellent for use in a table model computer where an accuracy of 5 per cent is sufficient. It also has occurred to the author that this amplifier would be excellent in a computer where a considerable number of amplifiers could be employed to solve problems in the following manner.

Because any function can be approximated by the Fourier series, which is

$$f(x) = A_0 + A_1 \sin wt + A_2 \sin 2wt + \ldots + B_1 \cos wt + B_2 \cos 2wt + \ldots \quad (24)$$

and because the first three sine and cosine terms plus $A_0$ will normally give a close approximation to general functions, and because either the sine or cosine terms can be generated employing three operational amplifiers per term, then a function could be closely approximated using 18 operational amplifiers. With this method employed, the need for a function generator would be eliminated. Therefore, an analogue computer could be built employing several operational amplifiers and one function multiplier. It is the author's belief that this type of computer would be excellent for exploratory work.

### Conclusion

From the text of this report it can be concluded that an analogue computer is capable of solving any ordinary differential equation of any degree or order, provided there are a sufficient number of operational amplifiers, function multipliers, and function generators available and, also, provided the function generators are capable of generating the required functions. Although it has not been discussed, computers of the analogue type are capable of solving simultaneous differential equations and partial differential equations, if real time is not essential. Partial differential equations are solved employing a method of approximation.

It is recommended that those interested in analogue computers refer to literature listed in the bibliography. Likewise a thorough understanding of the proofs and relative error of each individual component can be of great value to those persons who are interested in analogue computers.

### References

1. Elements of D-C Analog Computers, **G. A. Korn.** *Electronics*, New York, N. Y., April 1948.

2. Electronic Analog Computers (book), **G. A. Korn,** McGraw-Hill Book Company, New York, N. Y., 1952.

## An Electrical Engineer in Education

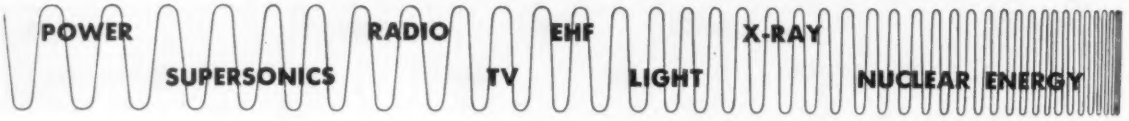
**S. R. WARREN, JR. (M '41, F '53), assistant vice-president, undergraduate engineering affairs, The Engineering Schools; and professor of electrical engineering, Moore School of Electrical Engineering, University of Pennsylvania.**

"Membership in AIEE has brought me some of the most inspiring and satisfying experiences of my professional—and personal—life. Men who conduct the affairs of AIEE for all of its members are competent professional men: they are able specialists, yet they understand the broad reaches of electrical engineering; they work hard and effectively with others, yet they maintain the integrity of their own ideas and ideals; they are serious minded and practical, yet they demonstrate tolerance and humor. To work with such men—no matter in what modest positions—is a great privilege and a strong motivating force. Among such men you do not encounter 'absolute certainty.' 'Absolute certainty is a privilege of uneducated minds—and fanatics.' (C. J. Keyser, 1922)."

Dr. Warren began his undergraduate program at the University of Pennsylvania, in 1924. His formal education was complemented by part-time and summer work with the Philadelphia Electric Company, the Bell Telephone Company of Pennsylvania, and International Resistance Company.

Dr. Warren's graduate program was combined with work on the technical aspects of the process of making x-ray films of the chest. This work brought Dr. Warren into the field of medical education—the instruction

# Electrical Engineering Education




in radiological physics of students of the School of Medicine and the Graduate School of Medicine.

He was awarded the doctor of science degree in electrical engineering in 1937. Beginning his teaching career as part-time instructor in electrical engineering in 1933, he became professor in 1949. Since 1951, he has combined teaching and administrative work. He first served as vice-dean of the Moore School of Electrical Engineering from 1951 to 1954; then as assistant vice-president, undergraduate engineering affairs, for the five Engineering Schools of the University of Pennsylvania.

Dr. Warren is coauthor of three books: "Apparatus and Technique for Roentgenography of the Chest," "Radiologic Physics," and "Electric Circuits and Fields." He has contributed technical articles to radiological and engineering journals, and to handbooks; and a chapter on acoustical principles to "The Principles and Methods of Physical Diagnosis," by S. S. Leopold, M.D.

He has been active in the affairs of Eta Kappa Nu, serving as its national president in 1955–56.

Despite Dr. Warren's broad activities he has maintained throughout his career a deep devotion to teaching. He believes that engineering education today faces a double challenge: first, to lead students to a deep understanding of the sciences that underlie the practice of engineering, and to an ability and willingness to face new problems; and second, to persuade students and the public that proper education in science and engineering may well turn out to be the most liberal education of our time.

"Able young men and women who study science and engineering must be convinced that college is an introduction to a lifetime of learning; and that this means, for each individual, the dynamic development of a way of living that is judged satisfactory by that individual. Such men and women have no need for 'absolute certainty'."

Dr. Warren began his AIEE activities in the Student Branch at the University of Pennsylvania. He has been active in the Philadelphia Section and has served on the following AIEE National Committees: Education (1947–56); Therapeutics (1949–51); Electrical Techniques in Medicine and Biology (1951–56, chairman 1951–53); Science and Electronics Division Committee (1951–56, chairman 1954–56); Award of Institute Prizes (1952–54); and Technical Operations (1954–56).

## Technical Personnel Receive Special Courses

To meet the growing demand for technical personnel, Allis-Chalmers Manufacturing Company (A-C) has inaugurated a new three-month company-wide training program under the direction of F. W. Churchill, drafting training supervisor for the firm's Power Equipment Division.

High School graduates selected on the basis of technical aptitudes constitute the first class. Sixteen phases have been set up to cover the three-month program. These include company organization, products, plant and office arrangement, company procedures and department functions, engineering mathematics, blueprint reading, curve plotting, and shop sketching.

Others are drafting and engineering standards, industrial testing, cost analysis, human relations, basic electricity, office machines, communications, and business English.

Augmenting lectures and required reading are movies, slides, models, exhibits, and experiments.

Upon completion of the course, the men will be assigned for final training and job selection in departments that use technical personnel. It is anticipated that their duties there will enable fully trained engineers to devote themselves more intensively to the more critical problems of their profession.

## A-C Network Analyzer Board Installed at University of Missouri

The department of electrical engineering of the University of Missouri, Columbia, Mo., has announced the opening of power system analyzer service to electric utilities, engineering organizations, and other industries.

The installation of an a-c network analyzer board at the University has been made possible by contributions from the following industrial organizations operating in the State of Missouri: Arkansas-Missouri Power Company, Blythesville, Ark.; Central Electric Power Co-operative, Jefferson City, Mo.; Empire District Electric Company, Joplin, Mo.; Kansas City Power and Light Company, Kansas City, Mo.; M. and A. Electric Power Co-operative, Poplar Bluff, Mo.; Missouri Public Service Company, Warrensburg, Mo.; Missouri Utilities Company, Cape Girardeau, Mo.; Saint Joseph Light and Power Company, Saint Joseph, Mo.; and Sverdrup and Parcel, Inc., Saint Louis, Mo.

Two other organizations made donations toward the purchase of the analyzer board: A. B. Chance Foundation, Centralia, Mo., and Union Electric Company of Missouri, Saint Louis, Mo.

The board will be available for service to any industrial concern approximately 20 weeks of the year. During the balance of the time, it will be used by the aforementioned contributor companies for system studies and by the University of Missouri for educational and research activities.

The 18 generator Westinghouse a-c network analyzer board is equipped with some of the most recent technical developments, including automatic scale selector and watt regulators. Six of the 18 generators are equipped with watt regulators which keep the power output from these generators constant regardless of changes made in the rest of the system. The automatic scale selector enables the operator to make readings without the necessity of manually changing scales, lights indicating the proper scale to read. Circuit metering selector equipment enables the operator to meter all parts of the analyzer from the operator's desk. A plotting table with space for 400 circuits is used to permit accurate and fast recording of data.

The a-c network analyzer board will be operated under regulations and policies formulated by an advisory committee consisting of one representative appointed by each of the contributing companies and three representatives of the University. The latter members will be the dean of the College of Engineering, the chairman of the electrical engineering department, and the supervisor of the analyzer. Prof. J. C. Hogan, associate professor of electrical engineering, will act as supervisor of the analyzer program. Prof. J. R. Tudor, assistant professor of electrical engineering, will act as associate supervisor.

The location of the a-c network analyzer board at the University of Missouri will provide a centrally located engineering service to many companies located in the Midwest.

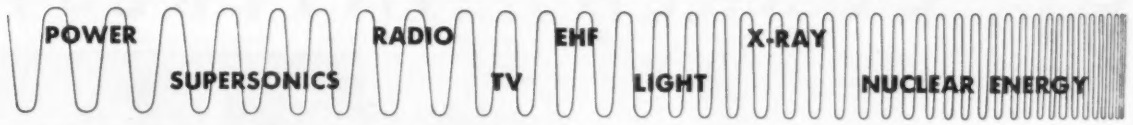
In providing this service, the department of electrical engineering expects to promote closer relationships between engineers in industry, members of the engineering faculty, and students who are interested in power system engineering. Both undergraduate and graduate students will have the opportunity to become more closely acquainted with the practical problems of power transmission and modern methods of solution. The interchange of ideas between practicing engineers, faculty, and students will stimulate interest in the power field among the students and will foster discussion of important problems which may be of mutual benefit to industry and the College of Engineering.

Information concerning the scheduling of service time and other details of operation of the a-c network analyzer may be obtained by writing to the Supervisor of the Network Analyzer Board, Department of Electrical Engineering, University of Missouri, Columbia, Mo.

## Professional Aides Trained in Engineering Secretarial Course

An engineering secretarial course, a unique educational program inaugurated last year by the Business Training College, Pittsburgh, Pa., is fast proving to be an aid to the busy professional engineer.

As soon as the program was initiated the




dean, Mrs. Phyllis Davis, received many calls from the engineering profession for the college's graduates. However, the course is of two years duration and the first graduates will not be available until June 1957.

It is the purpose of the college to give young men and women the type of training that will enable them to be of very great assistance to the busy engineer who does not have the time to concern himself with details that could be handled by a secretary who understands his language.

The Business Training College has become famous for training professional secretaries in the medical field, and graduates of this course have been very well accepted because they have been given sufficient medical background to cope with the professional terminology involved in medical secretarial assignments. The college planned the engineering course the same way, namely, to give the students a scientific background in addition to the secretarial skills such as shorthand and typing. The background subjects include chemistry, physics, advanced mathematics, and the terminology of the various fields of engineering. In addition, an intensive course in filing and blue print reading, with the use of the varityper, is provided.

The college realizes that for professional training it is most important to select students who have not only an interest in the field, but also the innate ability, aptitudes, and intellectual curiosity necessary for scientific professional training. Therefore, all prospective candidates for the course are given a series of tests for admission. On the basis of the test results and the high school record, only those students are accepted who have the qualifications to be successful.

The young man or young woman who is interested in an engineering career but who has been unable to spend four or five years in college finds through this new professional course an opportunity to become an associate and assistant as well as a secretary to the engineer.

## Test Equipment Research and Development Studied at NYU

The Department of Defense has established a national center at New York University (NYU) for monitoring research and development on electronic test equipment, it was announced recently by Dr. H. K. Work, director of the Research Division of the College of Engineering.

A team of NYU research engineers will serve as the staff for the Electronic Test Equipment Co-ordination Group, an agency of the Office of the Assistant Secretary of Defense for Research and Development.

The NYU team will study test equipment research and development throughout the electronics industry and the armed services. Other tasks include: providing technical assistance for analysis and evaluation of proposed and current electronic test equipment projects; calling attention to new laboratory advances and scientific trends in the United States and abroad that may be worth full development; anticipating future needs for certain equipment and initiating research to meet those needs; and ending unnecessary duplication of effort by reporting on industrial and service-wide developments.

Test equipment is one of the largest single areas in the electronics industry. It is sometimes more complex and costly than the end-item it serves.

Test equipment includes volt meters, built for a few dollars, and multimillion-dollar instrument ranges for guided missiles. It also is used in nearly every scientific research field. The most common electronic test device is the cathode ray oscilloscope that shows on a screen changes in electric current or voltage. It is used in research ranging from acoustics to zoology.

According to D. M. Goodman, NYU engineering scientist who directs the new program, the electronic test equipment industry has grown more than 15 per cent annually since 1947. Its total sales in 1955 were more than $150 million. The average annual growth for American industry in general has been from 3 to 4 per cent.

He stated that the current program at NYU arose to fill the need for a central active repository of information on today's rapid developments in electronic test equipment. The armed services, continually buying equipment and initiating research on equipment to serve new tasks, will find such a clearing-house particularly helpful.

NYU's contract is with the Navy Bureau of Ships, which is acting for all the armed services.

This marks the second major electronic co-ordination group in the NYU Engineering Research Division. Since 1949, NYU staff members have made up the secretariat for the Department of Defense Advisory Group on Electron Tubes; they monitor developments in the tube and transistor field. A third major group, concerned with electronic parts, is at the University of Pennsylvania.

NYU research engineers also have done research and development on several pieces of advanced test equipment in recent years. These include a transmission measuring set for measuring power in the frequency range from 100 kc to 10 mc, a microwave impedance bridge to measure and automatically display complex impedances over a broad frequency range, radio frequency signal seeking receivers, and piezo-electric crystal measuring devices.

The new team has started a comprehensive study of all available commercial test equipment. Later, they will divide into five working groups for the following classes of equipment: power and impedance measuring; frequency, time, and wave form measuring; signal generating; voltage and current measuring; and miscellaneous.

The team also will compile a central information index according to the five categories and cross-indexed under power range (1-, 100-, and 1,000- watt levels), frequency range (direct current, audio, ultrasonic, uhf, vhf, etc.), and physical configuration (wave guide structures, coaxial structures, or ordinary nontransmission line systems).

They will draw their information from industry, research laboratories, military and nonmilitary Government agencies, domestic and foreign technical publications, technical and scientific conferences, and personal visits. When necessary, the NYU group itself will do equipment research.

## AEC Approves Loan of Uranium to Four More Schools

The Atomic Energy Commission (AEC) has approved four loans, each of 5,500 pounds of natural uranium metal, plus neutron sources, for Georgia Institute of Technology, Atlanta, Ga.; the University of Maryland, College Park, Md.; Cornell University, Ithaca, N. Y.; and Yale University, New Haven, Conn. The uranium and neutron sources will be used in subcritical assemblies for the training of nuclear engineers.

The subcritical assembly consists of an arrangement of uranium rods in a moderator such as graphite or ordinary water. When the neutron source is introduced, nuclear fission is produced, but the reaction cannot be sustained without the presence of the neutron source.

Such assemblies do not require the complex control mechanism, expensive shielding, or heat removal equipment of nuclear reactors, and may be used for many laboratory exercises in nuclear engineering training.

The 5,500 pounds (2,500 kilograms) of uranium metal to be loaned each institution will be in the form of rods enclosed in aluminum. This brings to 12 the number of loans of this type to nonprofit educational institutions. Loans have already been approved for Alabama Polytechnic Institute, New York University, University of Florida, Virginia Polytechnic Institute, Massachusetts Institute of Technology, the City College of New York, Iowa State College, and Stanford University.

The Commission for sometime has been supplying certain materials for these assemblies without a use-charge being made, subject to the availability of the material and to a determination that such loans will advance the Commission's program to assist in alleviating the current shortage of nuclear scientists and engineers.

# OF CURRENT INTEREST

*ENGINEER F. K. Becker, who is working on development of new Picture-phone system, demonstrates how one experimental model operates.*

## Picture-Phone Uses Ordinary Telephone Wires

A TELEPHONE that transmits pictures along with sound has taken a big step towards commercial feasibility, Bell Telephone Laboratories have announced.

Scientists and engineers at the Bell System's research and development organization have used an experimental "Picture-phone" system to transmit recognizable pictures over short and long distances, even as far as from New York, N. Y., to Los Angeles, Calif.

Experimental pictures vary in size from $1 \times 1^1/_2$ inches to $2 \times 3$ inches, and are viewed from one to two feet away. Unlike television, a new picture is displayed every two seconds. It has good black-and-white contrast and the person at the other end of the line is recognizable. Head and shoulders can be seen and facial expressions are readily apparent.

The picture-phone described is the first system of its kind to use a pair of ordinary telephone wires. This is what gives it promise of being commercially feasible. Only one other line, consisting of a pair of wires like the regular telephone line, would be installed on the customer's premises to carry the picture.

It will be possible for a caller's picture to be "dialed" like an ordinary telephone call, provided the switch on the picture equipment is turned on at both ends of the line. If the switches are off, the telephone call will be completed without pictures. The picture can also be turned on after a conversation is under way. It would be impossible for a customer to be seen by the caller unless he flipped on the switch.

The Picture-phone system differs from television in this way: television sends 30 pictures a second and uses high frequencies which require relatively expensive coaxial cable and microwave radio relay systems, and provide an extremely detailed picture of a large scene. The Picture-phone sends a smaller and less detailed picture every two seconds. The fact that this image can be transmitted over standard low-frequency telephone channels makes it possible to use ordinary telephone wires, like those running to the homes of telephone customers.

The picture equipment is still undergoing development and evaluation and is not ready for manufacture or commercial use. There are several experimental units, different in size and appearance, but they operate on the same basic principles. Engineers believe that a system based on these principles can eventually overcome the cost barrier.

The Picture-phone, after further development, could be offered as a separate, optional telephone service. The unit would be made much more compact than the present experimental apparatus.

One of the experimental Picture-phones as it has been operated in the laboratory uses a miniature television camera mounted on a desk. Another experimental unit incorporates the camera into the same unit as the screen. Instead of the bright lights required on a TV stage, the Picture-phone will require only the natural daylight ordinarily available in a bright room, or moderate amounts of artificial light.

Present picture viewing apparatus is about the size of a small suitcase. Bell engineers expect to reduce the size drastically. Associated picture transmitting and receiving equipment must also undergo further development and design work.

### Background

Operation of the picture-phone system has been made possible by slowing down the rate of transmission of picture information to such an extent that the required bandwidth can easily be handled by conventional telephone circuits. The raster is made up of 60 lines, each of which may have a maximum of 40 dots. Thus, each complete frame may be thought of as being made up of 2,400 dots. If a single frame were transmitted each second, an over-all bandwidth of 1,200 cycles per second would be necessary. With the present system, one complete picture is transmitted every two seconds, requiring a bandwidth of 600 cycles per second.

This 600-cycle video band contains very

low-frequency components which might suffer undue attenuation during transmission over phone lines. Therefore, a carrier scheme is employed in which the video signal amplitude-modulates a 1,200-cycle carrier. The transmitted intelligence is then a conventional amplitude-modulated double-sideband signal with a frequency range of 600 to 1,800 cps. This signal lies within the range of optimum transmission of telephone lines, and can be treated exactly like a voice signal. It can be passed through repeaters, and transmitted via microwaves, coaxial cable, twisted pair, or open wire lines.

An analysis of the over-all system can best be made by referring to the block diagram. This diagram outlines one possible line-up of components which has been tested experimentally.

A conventional television camera of the type employed in industrial television systems is indicated. This camera contains a Vidicon tube and the necessary horizontal and vertical sweep circuits for producing a raster. These circuits are so adjusted that the 60-line raster mentioned is obtained, with one complete scan occurring every $^1/_{20}$ second.

Because the transmitted picture repetition rate is only one every two seconds, a total of 40 scans is available in the 2-second interval. One of these scans is arbitrarily selected and the remaining 39 are unused. The information in this scan is recorded on a magnetic drum which is rotating at a speed of 20 revolutions per second. All of the picture information for a single frame is thus recorded on a single rotation of the drum.

By means of suitable gating and timing circuits, this stored information is then picked off the drum at $^1/_{40}$ the rate at which it was recorded. Thus, by the time it has turned 40 revolutions (an interval of two seconds), all the information from a single scan has been passed on to the modulator, and the drum is erased and made ready for the next picture. At this point, timing and synchronizing data are combined with the signal to be transmitted. Such data are added in much the same manner as synchronizing information is combined with a conventional television signal.

It is possible to take advantage of the storage properties of the camera tube itself, and thus eliminate the magnetic drum memory system. By means of a suitable shutter arrangement, the image tube can be made to receive a momentary image once every two seconds, and then the whole two seconds used for the scanning procedure. The signal thus derived can be sent directly to the modulator. Sufficient experience has been gained with this technique to indicate that it is feasible.

Conventional modulating and demodulating techniques of the type used in telephoto equipment are employed in the system. At the receiver, the synchronizing information is removed from the signal, and used to control suitable horizontal and vertical sweep circuits. The remaining picture information is then presented to a suitable display medium which, in the case of the block diagram, is a pair of Iatron direct-view storage tubes.

The Iatron presently being used is a recently developed commercially available electrostatic storage type of tube which uses electrostatic deflection. It has an inner screen just behind the fluorescent coating on which a picture may be stored by means of an electron gun and suitable scanning circuits. During this storing process, the face of the tube remains dark. Once the picture is stored, it may be made visible by means of a flood of electrons provided by a second electron gun. The picture will last for several minutes, if desired, and may be erased at will by applying a suitable potential to one of the electrodes.

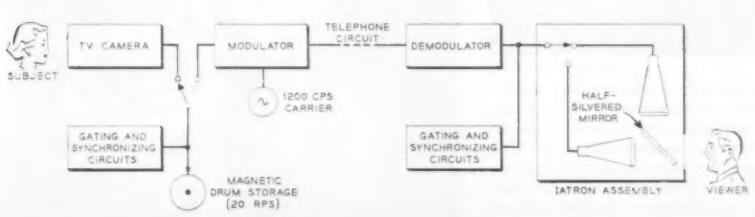
As can be seen from the block diagram, the present equipment employs two Iatrons placed at right angles to each other, with a half-silvered mirror located as shown. Thus, the viewer can see the image on either of the tubes when the other one is dark. The technique is to write the information on one tube while the other is being viewed, and then to switch over so that a new picture is written onto the second tube while the first is being viewed. Since each picture appears for two seconds, the viewer sees a picture change every two seconds.

An alternative receiving arrangement which has been successfully tested is a combination of a magnetic drum storage system and an ordinary cathode-ray tube of small size. The drum memory system stores the incoming picture information, and then feeds it to the cathode-ray tube. Two magnetic drums are necessary so that one is storing information from the telephone line while the other is feeding information from the previous scan to the picture tube. This arrangement is essentially the reverse of the magnetic storage system employed in one version of the transmitter.

Still another receiving system which is being investigated is the use of a facsimile-type recorder that prints the pictures on a small strip of paper, one every two seconds. Brightness is then limited only by the illumination on the picture once it appears on the strip, and a prism arrangement can be employed for viewing purposes so that to the viewer the image remains stationary for the full two seconds even though the strip of paper is moving. This system has the added advantage that the pictures are a permanent record for future reference.

### Future Developments

In its present form, equipment for the




**BLOCK DIAGRAM outlines one possible line-up of components.**

## Future Meetings of Other Societies

**Pennsylvania Electric Association,** Fall Meeting:
*Transmission and Distribution Committee,* November 1–2, Shenango Inn, Sharon, Pa.

**SAE,** National Meeting:
*Diesel Engine,* November 1–2, Drake Hotel, Chicago, Ill.
*Fuels and Lubricants,* November 8–9, Mayo Hotel, Tulsa, Okla.

**5th Annual Instrumentation Conference,** November 1–2, School of Engineering, Louisiana Polytechnic Institute, Ruston, La.

**ISA, Symposium on Process Data Logging,** November 7–8, Bellevue-Stratford Hotel, Philadelphia, Pa.

**SFSA,** 11th Annual Conference, November 7–9, Carter Hotel, Cleveland, Ohio

**NACE,** Technical Fall Division Meetings:
*Southeast Region,* November 8–9, Charlotte, N. C.
*Western Region,* November 15–16, Lafayette Hotel, Long Beach, Calif.
*North Central Region,* November 15–16, Hotel Statler, Detroit, Mich.

**American Petroleum Institute,** November 12–15, Conrad Hilton Hotel, Chicago, Ill.

**National Industrial Development Exposition,** November 12–16, Coliseum, New York, N. Y.

**NEMA,** November 12–16, Traymore Hotel, Atlantic City, N. J.

**Investment Casting Institute,** 4th Annual Meeting, November 13–15, Sheraton Cadillac Hotel, Detroit, Mich.

**National Association of Ice Industries,** Annual Convention, November 13–16, The Biltmore Hotel, Atlanta, Ga.

**IRE, Symposium on Optics and Microwave,** November 14–16, George Washington University, Washington, D. C.

**ORSA,** 10th National Meeting, November 15–16, Mark Hopkins Hotel, San Francisco, Calif.

**New England Radio-Electronics Meeting,** November 15–16, Hotel Bradford, Boston, Mass.

**ASME,** Annual Meeting, November 25–30, Statler Hotel, New York, N. Y.

**3rd International Automation Exposition,** Fordham University School of Business, November 26–27, Hotel New Yorker and Trade Show Building, New York, N. Y.

**9th National Chemical Exposition and Technical Meeting,** November 27–30, Cleveland Public Auditorium, Cleveland, Ohio.

**National Warm Air Heating and Air Conditioning Association,** Annual Convention, November 27–30, Conrad Hilton Hotel, Chicago, Ill.

**International Ozone Technology Conference,** November 28–30, Armour Research Foundation, Chicago, Ill.

**American Mining Congress,** Annual Meeting, December 3, New York, N. Y.

**SPI,** Film, Sheeting and Coated Fabrics Conference, December 4–5, Hotel Commodore, New York, N. Y.

**5th Annual Symposium,** Technical Progress in Communication Wires and Cables, December 4–6, Berkeley-Carteret Hotel, Asbury Park, N. J.

**Instrumentation Conference and Exhibit, PGIRE,** December 5–7, Biltmore Hotel, Atlanta, Ga.

**AIME,** 14th Annual Electric Furnace Steel Conference (Celebrating 50th Anniversary of electric arc process), December 5–7, Morrison Hotel, Chicago, Ill.

Picture-phone is rather bulky and expensive. However, a number of avenues are being explored to reduce size, complexity, and cost.

An appreciable reduction in the size of the receiving equipment would be possible if the two-Iatron tubes could be combined into one envelope. Work is progressing in this direction.

Exploratory work is under way to determine the combination of picture repetition rate and resolution which will make best use of the available bandwidth. The picture rate can be increased at the expense of resolution, or the resolution can be improved by decreasing the picture rate. Extensive subjective tests will be necessary to determine the optimum combination.

Further miniaturization of both the transmitting and receiving equipment may be accomplished by using transistors in the electronic portions of the circuit. Such transistorization reduces the heat developed by the various components, thus permitting the use of a smaller over-all enclosure.

# Modern Research Center Dedicated by Westinghouse

WITH THE OFFICIAL OPENING of Westinghouse Electric Corporation's new research laboratories, the electrical manufacturing industry has been provided with its most modern research facility to date.

Occupying a 72-acre site in Churchill Borough, about 10 miles east of downtown Pittsburgh, Pa., the structure is a 3-story L-shaped building of red face brick trimmed with stainless-steel panels on the office wings. The gross area is 313,000 square feet, or more than seven acres. The move from the old laboratories in Forest Hills to Churchill Borough expanded the research facility space 2.3 times.

Work is organized into 11 departments, including chemistry, electromechanics, electronics and nuclear physics, insulation, magnetics and solid state physics, mathematics, mechanics, metallurgy, physics, semiconductor and solid state physics, and technology.

Equipment in the Laboratories ranges from such items as a 15-ton bearing test machine to a quartz bar microbalance which is suspended on a wire finer than a human hair and would be taxed to capacity if required to weigh more than a single speck of dust. A cyrostat can plunge temperatures to near absolute zero (−459 F). Elsewhere, the atmosphere of outer space is approached with delicate apparatus which will create nearly perfect vacuums. Pressures as low as one millionth of a billionth of an atmosphere have been achieved in this laboratory for several experiments.

More than 700 men and women work at the laboratories, of which more than 450 are professional scientists, laboratory technicians, and assistants. Of the professional personnel, 38 per cent are physicists, 24 per cent are chemists, 13 per cent are electrical engineers, 11 per cent are mechanical engineers, 7 per cent are metallurgists and 4 per cent are mathematicians. Of the men hired from colleges and universities in 1956, 72 per cent held doctor's degrees before being employed.

About 30 per cent of the Laboratory's effort is in work fundamental to the electrical industry, but not directed toward a particular product development. About 55 per cent is co-ordinated with long-range plans of product divisions, most of it being basic research. Eight per cent is taken up in governmental activity. Seven per cent is devoted to product development mostly in highly specialized fields.

### Electroluminescence

Important progress made in the field of lighting was demonstrated in the unveiling of the world's first room illuminated solely by electroluminescence. Lighting was accomplished by means of 112 one-foot-square panels spread over the ceiling and three walls of the room, using a 350-volt 3,000-cycle source.

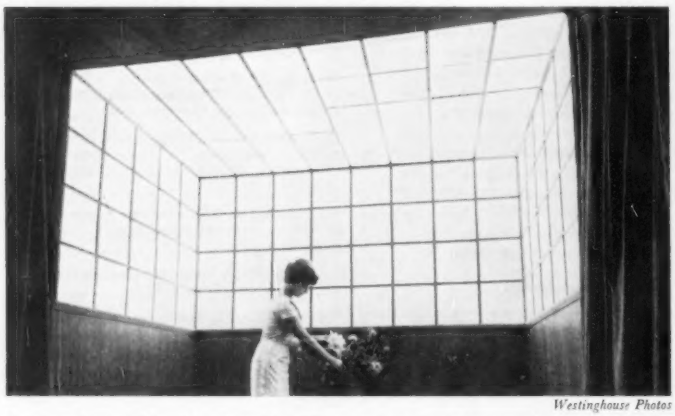
What is called electroluminescence today was first discovered in 1936 by a French investigator Professor Georges Destriau. Working in his laboratory with a small group of co-workers, Professor Destriau explored this new phenomenon until in 1947 he was able to publish a review paper that set forth many of the properties of electroluminescent cells.

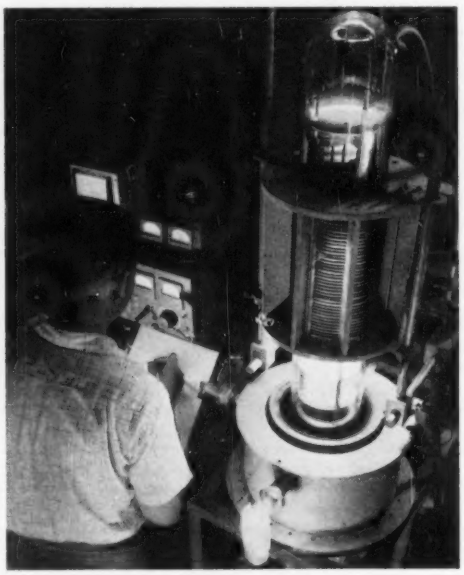
An electroluminescent cell is constructed something like a sandwich in which the phosphor is placed between two conducting plates very much like those of a capacitor. When proper voltage is applied between the conducting plates, the phosphor will give off light. The cell currently being used consists of a glass plate bearing a transparent, conducting coating on which is sprayed a mixture of phosphor powder in a plastic binder. On top of this phosphor layer is evaporated a film of aluminum which acts as a second conducting contact for the cell.

Because some phosphors have more than one emission band, frequency can affect the color emitted. One phosphor, for example, is green when power below a frequency of 1,000 cycles is applied. Above 5,000 cycles, the light emitted is blue. In between, it is varying shades of blue-green.

Brightness of electroluminescence is proportional to both the frequency and voltage of the electricity applied. Raising either one increases the brightness. Thus, 2,000 foot lamberts has been obtained by using a 600 volt, 20,000-cycle power source. Raising the voltage too much causes new problems, such as dielectric breakdown.

Unlike brightness, peak efficiency of 9 lumens per watt was achieved by using electricity of only a few hundred cycles and a





*Westinghouse Photos*

**WALLS AND CEILING (*above*) made of light. Panels as thick as window glass line this room, providing light from man's newest and most promising light source—electroluminescence. SECRETS OF SUPER METALS (*right*) are probed. In a temperature of 4,000 F in the airless glass chamber of this high-temperature vacuum furnace, an experimental metal alloy is treated. An atmospheric pressure one billion times rarer than the air we breathe is produced in the glass testing chamber. Designed to explore metals of the future—high-temperature alloys for guided missiles, jet engines, and gas turbines—scientists have produced an alloy which, at temperatures above 1,800 F, is stronger than any known metal.**

few hundred volts. Applying higher or lower values only decreases the efficiency. Present efficiency of 9 lumens per watt may be compared with 16 for a 100-watt incandescent lamp and 60 to 70 for a 40-watt fluorescent lamp. The probable maximum efficiency in the future for the three lighting forms is 240 lumens per watt for electroluminescence, 22 for incandescent lamps, and 100 for fluorescent lamps.

#### Vibrating Rate Gyro

A new rate-type gyroscope, designed for use on aircraft and missiles, falls into the general classification of a vibrating rate gyro or "vibragyro." As the name implies, its gyroscopic forces result from a *vibrating* mass and not a *rotating* mass as in the conventional gyroscope.

A simple tuning fork can be used to demonstrate the basic principles of the vibragyro. If the fork is turned about a vertical axis, with the masses vibrating toward and away from the axis, gyroscopic forces are developed in the form of a couple which produces an oscillating torque about the input axis. This torque produces a small deflection whose amplitude is proportional to the rate of turn or input velocity. The phase of torsional vibration compared with the phase of the vibrating masses indicates the direction of the input velocity.

Work on the vibragyro was started in the Research Laboratories over two years ago but only recently has a simple practical model been developed. Two masses are attached to the sides of a rigid rectangular frame having two heavy ends which might be compared to bases of a double tuning fork arrangement. This assembly is supported by two wires which also serve to isolate the vibrating forces from the base of the vibragyro. A small transducer is used to change the gyroscopic angular vibrations to an alternating electrical signal whose amplitude is proportional to the rate of turn.

#### Automatic Experimenter

Also announced was the development of a new "electronic brain," which promises to revolutionize the control of complex industrial processes. Called "Automex," the "brain" has a built-in intelligence, enabling it to distinguish between right and wrong decisions, reported Dr. Morris Ostrofsky, manager of the mathematics department at the Laboratories.

The key to Automex's function is that it will, by repeated experimentation, try to reach a given goal with a capacity for dispassionate judgment in distinguishing between success and failure.

Automex's initial steps may be rather sweeping as it cuts the problem down into smaller areas, but the computer then takes smaller and smaller steps as it seeks its way toward the goal. Occasionally, it may take a deliberate false step as it "makes up its mind" about the most successful course.

In one application, Automex would be useful to a chemist who is adding two or more solutions together to obtain a reaction in a heated container. The Automex would enable him to find out how changes in the temperature or certain amounts of the solutions would affect the reaction.

It was emphasized that Automex is not limited to control of a process involving only two variables.

# Electronic Devices Operate Literally "Red Hot"

THE PENETRATION of a critical temperature barrier in the development of guided missiles and supersonic aircraft was demonstrated in New York, N. Y., when General Electric Company (GE) scientists exhibited laboratory models of electronic devices and circuits operating literally "red hot." The achievement was described as a major step toward overcoming the inability of electronic controls to withstand the tremendous heat generated by air friction at extreme speeds.

An equally important "plus" feature of the new electronic circuits is their ability to operate for long periods while exposed to intense nuclear radiation in a reactor.

#### Defense Importance

Tremendous defense implications have been attributed to the heat-resistant, radiation-tolerant electronic devices by Dr. C. G. Suits, GE vice-president and director of research. He said that the rapid progress reflected in these demonstrations is the result of "extraordinary teamwork" among the GE Research Laboratory at Schenectady, N. Y., nearly a dozen other GE departments and laboratories, and various United States defense agencies.

Radically new electronic concepts incorporated in these components and circuits represent a crucial breakthrough of the "thermal barrier" and give new impetus to the nation's guided missile, satellite, and supersonic plane programs.

#### Variety of Components Used

Inside glowing electric furnaces and surrounded by blazing blow-torches, General Electric's new vacuum tubes, capacitors, resistors, transformers, inductors, wires, printed circuit boards—and even an electric motor—were operated at temperatures ranging from 900 to 1,500 F. Metals such as titanium and special laboratory-designed ceramics play important roles in the design and construction of high-temperature components.

In successful tests, electronic assemblies have been operated at high temperature for more than 1,000 hours in the neutron flux of the graphite reactor at the Oak Ridge (Tenn.) National Laboratory.

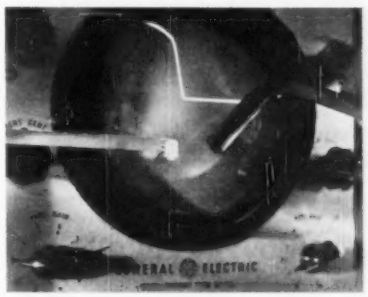
Several components were developed up to 1945 that could operate at 300 F, but the over-all reliability limit was, and in much of present-day equipment still is, about 200 F. Recent emphasis on guided missiles and supersonic aircraft has greatly increased the requirements, but until now extensive research and expenditure has produced only a few components capable of operation at 500 to 600 F.

To help show the versatility of the high-temperature electronic components, GE Research Laboratory scientists demonstrated a "hi-fire" phonograph with the amplifier glowing brightly in a 1,500-F oven. There was sufficient volume to fill the large demonstration room and surprising fidelity in reproducing the "hot 'hot jazz' record" used in the demonstration. Also shown was another circuit that picked up and amplified a radio signal even while the equipment was in the direct flame of three blowtorches.

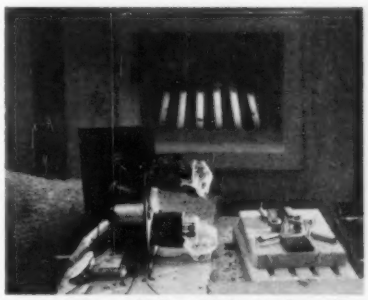
Other less dramatic, but scientifically significant, demonstrations included two multivibrator (electronic pulsing) circuits operating in electric ovens at temperatures ranging from 1,000 to 1,500 F. Both of these demonstrations involved circuits using vacuum tubes, resistors, capacitors, and print-boards.

#### Missile Requirements

The problems surrounding the development of guided missiles including the so-called "ICBM" (intercontinental ballistic missile) were described. The electronic circuits, resistors, amplifiers, transformers, and tubes in a guided missile must be designed to operate reliably in two sources of heat: internal and external. The multitude of tasks required of a guided missile, combined with the all-important necessity of keeping weight and unused space at an absolute minimum, results in a severe con-




**VACUUM TUBE** (laboratory model of 6BY4 microminiature ceramic tube) operates—as indicated by oscilloscope pattern in background—even when red-hot in the flame of a blowtorch.



*GE Research Information Services Photo*

**SIDE-BY-SIDE COMPARISON** shows ordinary electronic circuit with a new GE high-temperature circuit after being placed in electric oven at 1,500 F. Ordinary circuit stopped working almost immediately; began to melt and disintegrate. The new circuit—composed of special types of vacuum tubes, resistors, capacitors, wires, and printed circuit board—has operated at 1,500 F for thousands of hours.

centration of many electronic components in a small volume.

The ICBM is a classic example of an application of high-temperature components to the problem of external heating. It must descend from extreme altitudes at velocities of about 10,000 miles per hour and re-enter the dense layer of air surrounding the earth. Within this envelope of air, friction between the ICBM and the air around it generates heat equal to that heat generated by a half dozen or more of the world's largest steam turbines. If not dissipated, this heat rise can make ICBM electronic components either malfunction or fail.

The new components' tolerance to nuclear radiation was described as an important "extra feature" by G. W. Newton, manager of application engineering at the Aircraft Nuclear Propulsion Department.

"The Aircraft Nuclear Propulsion Department for the past two years has made an extensive effort to develop power plant components tolerant to nuclear radiation," he said. "During the course of the development, we found that many materials that are susceptible to damage by heat at temperatures less than 500 C are also susceptible to damage from nuclear radiation. Now, with this demonstration of nuclear radiation tolerance, one of the technological advances needed to better meet the objectives of the Aircraft Nuclear Propulsion Department was at hand."

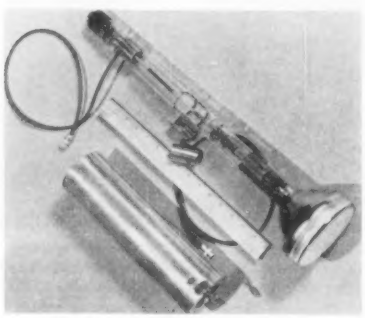
The tests in which electronic circuits were operated for over 1,000 hours in the graphite reactor at the Oak Ridge National Laboratory were described in some detail.

## Picture Tube Receiver Functions in Single Package

A radically new type of cathode-ray tube for radar, television, and other electronic display applications has been developed recently. The new electronic device was demonstrated publicly for the first time at the Western Electronic Show and Convention.

"Wamoscope," as the new tube is called, combines most of the essential functions of a microwave receiving set in a single tube envelope, eliminating many of the tubes and components required by conventional receivers.

Dr. R. M. Page, associate director of research for electronics at the Naval Research Laboratory, said that the development of the tube was carried out under an Office of Naval Research contract by Sylvania Electric Products Inc. in co-operation with the Laboratory.



WAMOSCOPE, is about 20 inches long, with a 5-inch diameter fluorescent screen. The solenoid shown fits over the traveling-wave tube section to focus it, and the tube's r-f transducers are also included.

In a radar receiver utilizing the Wamoscope, microwave signals go directly from the antenna into the tube, where, in a single envelope, the signals are amplified, detected, and displayed on the tube's fluorescent screen. When compared with a conventional radar receiver, this means that the local oscillator, mixer, intermediate frequency amplifier, detector, video amplifier, and their associated circuitry are eliminated.

An important feature cited is the wide selection of channels possible in the Wamoscope, which operates over a mirowave frequency band of 2,000 to 4,000 mc.

The Wamoscope name is derived from the technical term "wave-modulated oscilloscope," which was suggested by three NRL scientists associated with the project.

The official designation of the Wamoscope now being shown in tube type *6762*. Pilot quantities of the tube have been produced, and are being used with Navy approval in connection with high-priority research and development projects in all three armed services. Additional Wamoscope types operating in different frequency bands and incorporating other features are now under development.

Although the Wamoscope type *6762* has a 5-inch bulb and a P-7 phosphor, there is no practical limitation to either the size of the face of the tube or the type of phosphor used.

The operation of the Wamoscope is based upon velocity-sorting the electrons which emerge from the end of the helix of the traveling wave tube section. A d-c beam of suitable voltage is passed down the helix. With an r-f input, the beam interacts with the r-f fields on the helix so that the beam is velocity and current modulated in accordance with the amplitude of the r-f signals. The velocity modulate beam enters the region where the special electron-optical system is located. By applying a suitable bias voltage to an aperture in the electron-optical system, the electrons that have greater velocity than the d-c velocity pass through the aperture and are allowed to impinge on the screen of the cathode-ray tube whereas the slower electrons are reflected.

Two basic advantages of the new tube are: (1) reduction in the number of tubes and components inasmuch as the one envelope provides amplification, detection, and display of r-f information as well as elimination of the local oscillator, mixer, intermediate frequency amplifier, detector, and video amplifier, and their associated circuitry increases the reliability of the equipment; (2) wide bandwidth of the tube which enables the amplification, reproduction, and display of extremely short pulses, and the display of information contained in wide-band systems.

## AEC Nuclear Energy Policies and Developments

*Foreign Nations To Obtain Reactors.* The United States Atomic Energy Commission (AEC) and the United States State Department are distributing to interested embassies and United States industrial organizations the details of the program for United States grants of up to $350,000 for research reactor projects undertaken by friendly nations that have Agreements for Co-operation with the United States.

The procedures are substantially those already used and tested in handling the first requests for assistance received following the offer made by President D. D. Eisenhower last year to strengthen and advance the atomic research programs of those nations included in the bilateral agreement program.

As previously announced, grants of $350,000 each have been made to Brazil, Spain, Denmark, and the Netherlands. Negotiations for similar commitments are in progress with several other nations. The Congress appropriated $5.5 million for the program during the current fiscal year.

These grants may be made toward the financing of an approved reactor project providing the total of $350,000 is not more than one half of the actual cost. In addition to the reactor itself, a project may include experimental equipment, supporting facilities and activities necessary to make it an operable and useful training and research facility. The grants are payable when the recipient nation certifies that the project has been completed.

The detailed procedures are available from the AEC for background and reference.

*Rights Waived to Inventions or Discoveries.* The AEC has given notice that it proposes to waive its statutory rights to inventions or discoveries resulting from the use of certain materials made generally available. Notice of the proposed policy and of the materials involved was published in the "Federal Register," September 18, 1956.

The published notice gives opportunity to the public to comment within 30 days after the date of publication.

The AEC proposes to waive certain rights granted it under Section 152 of the Atomic Energy Act of 1954. The proposed action supplements a policy followed for several years, so as to encourage research and development in atomic energy, that it acquires no rights in inventions or discoveries resulting from the sale or distribution of isotopes and certain standard irradiation services. More recently a similar waiver was adopted in relation to Restricted Data obtained under AEC-issued Access Permits and in respect to activities under licenses issued by the AEC.

The proposed policy is based on the belief that where information, materials, and services are made available generally to the public, and inventions or discoveries result from their use, the inventors should be able to obtain patent rights.

The materials now covered by the waiver are:

(1) Source materials, special nuclear materials, and heavy water sold or leased by the AEC for use in private atomic energy development.

(2) Radioactive and stable isotopes, special materials, and materials resulting from the performance of irradiation services provided by the AEC, at established prices and charges, through Oak Ridge National Laboratory, Oak Ridge, Tenn. (electromagnetically enriched and other stable isotopes, radioisotopes, special materials, services); National Reactor Testing Station, Idaho Falls, Idaho

(irradiation services); Argonne National Laboratory, Lemont, Ill. (irradiation services); and Brookhaven National Laboratory, Upton, L. I., N. Y. (irradiation services and radioisotopes). Special arrangements as to inventions or discoveries are made where persons or groups of persons use AEC laboratory facilities. The waiver does not include inventions or discoveries by the AEC or AEC contractor personnel made during the performance of an irradiation service.

(3) Radioisotopes sold at 20 per cent of the catalogue price for biomedical and agricultural research under its program to encourage and stimulate the use of radioisotopes in the life sciences.

The notice provides that the proposed rule does not affect the provisions of any contractual arrangement to which the AEC is a party.

*Naval Research Laboratory To Operate Research Reactor.* With completion of a preoperational inspection by representatives of the AEC, the Commission has issued a license to the Naval Research Laboratory, Washington, D. C., to operate an atomic reactor for use in research.

The license is for a 20-year period dating from April 29, 1955, when construction of the reactor was authorized, and expiring April 29, 1975.

Located at the Laboratory's Southwest Washington site, the reactor is of the "pool" type. The reactor core is suspended in water, which acts both as moderator to slow the neutron flow and as a shield against radiation. The water is contained in a pool 40 × 26 feet, and 20 feet deep, in which the reactor core is suspended from a movable platform or bridge spanning the pool.

Fueled by U-235 in the form of uranium-aluminum alloy plates, the reactor will operate initially at a power level of 100 kw.

The AEC has also issued a special nuclear material license to the Laboratory to receive and possess 5 kilograms of contained U-235 in fuel element assemblies and 6 grams of contained U-235 in neutron measuring instruments incorporated in the reactor.

The Naval Research Laboratory reactor, the first to be licensed in Washington, is similar in design to one which has been in operation for several years at the Oak Ridge National Laboratory, Oak Ridge, Tenn. A simplified version of this reactor type was exhibited by the United States at the Conference on the Peaceful Uses of Atomic Energy held in Geneva, Switzerland, in August 1955.

*JTF-7 Commander Makes Preliminary Reports.* Rear Admiral B. H. Hanlon, Commander, Joint Task Force Seven (JTF-7), has returned from the Marshall Islands following the recent conclusion of the *Redwing* test series, and has made preliminary reports of the tests to Secretary of Defense C. E. Wilson and Chairman L. L. Strauss of the AEC.

Adm. Hanlon reported that the programmed number of tests was made of nuclear devices ranging widely in yield, some in the kiloton and some in the megaton range, and that the energy released by each of the devices fell within the range of estimates made prior to firing. Adm. Hanlon reaffirmed that the energy yield of the largest was substantially less than the largest device detonated in the *Castle* test series.

Following the firing of the concluding detonations, light fallout occurred on parts of Eniwetok Atoll occupied by the JTF-7. The fallout did not necessitate evacuation of personnel and no special protective measures were required.

*Radioactive Drug.* Reserpine, a drug produced by the *Rauwolfia* plant and used for the treatment and cure of certain mental disorders and for the reduction of high blood pressure, has been produced in a radioactive form at the AEC's Argonne National Laboratory.

The radioactive drug was produced by growing the plant in an atmosphere containing radioactive carbon dioxide by a research team which consisted of E. A. Peets and Dr. Arthur Schulert of Columbia University's Lamont Geological Observatory and Dr. John Skok and William Chorney of the Argonne National Laboratory's Biological and Medical Research Division.

The radioactive reserpine will be utilized at Columbia University in important biological studies involving physiological and biochemical actions in the animal body. By labeling the reserpine molecules with radioactive carbon, it is possible to trace their chemical pathways throughout the body with great precision. It is expected that these studies will contribute important medical information on the use of the drug.

Young *Rauwolfia* plants were grown in small hermetically sealed greenhouses in which the atmospheric carbon dioxide was enriched with radioactive carbon dioxide. The plants were grown under these conditions for about six weeks. After harvesting, the roots were dried, ground and the reserpine extracted.

*Nuclear Reactor for Medical Research and Therapy.* A part of the AEC Brookhaven National Laboratory at Upton, L. I., N. Y., will be the research center containing a nuclear reactor designed specifically for medical research and therapy. The installation was designed by the architectural firm of Eggers and Higgins following preliminary designs by the Laboratory's architectural planning department in collaboration with its medical department. The buildings are scheduled for completion by late 1957.

The one-story medical center at Brookhaven will cover 2.7 acres of an 11-acre site. It will house research laboratories for medical physics, pathology, microbiology, biochemistry and physiology, plus a 48-bed research hospital, and an industrial medicine branch for Brookhaven personnel. A central facility will provide general laboratory and hospital services.

The nuclear reactor will be housed separately in a circular steel building 60 feet in diameter and 54 feet high, covering a gross area slightly less than 5,000 square feet. The core, process instruments, 43,000-pound shutters for the two reactor ports, wiring and console will be supplied and installed by separate contractors at a total cost of $178,840.

The entire medical research center, including the reactor, is scheduled for completion in 1958 at a cost of $6 million exclusive of design and engineering.

Cooled and moderated by ordinary water, the reactor will utilize an alloy of enriched uranium and pure aluminum as fuel. Four cadmium-boron control rods will be held above the core by electromagnets. Any rise in reactor power beyond a desired point would cause an interruption of electrical current to the magnets and the control rods would automatically drop.

The core of the reactor, less than two feet in diameter and 26 inches high, will contain 18 fuel elements arranged in a cylindrical configuration and set in an aluminum tank 2 feet in diameter and 22 feet high The graphite reflector encasing the core will be surrounded by a shield three to five feet thick, and will be cooled by the movement of filtered air through cooling passages in the graphite. This and all other air exhausted from the building will be completely filtered to remove any contamination before it is discharged from a 150-foot stack.

The coolant-moderator will be pumped through the core to the top of the reactor tank and then flow back to the basement through a shielded pipe. There, by means of a heat exchanger, it will be divested of the heat acquired in passing through the core, and will return to the bottom of the reactor for recirculation. A portion of this water will be continually drawn off and passed through a purifying system before it rejoins the main stream for reuse.

Two ports, one on each side of the reactor, will permit beams of neutrons from fissioning atoms inside the core to pass out into treatment rooms. When a beam is not in use, each port will be closed by a 43,000-pound shutter. The shutters, which can release or close off the beam within three seconds, will be controlled by the administering doctor from behind a shielding wall two feet thick.

The third face of the reactor will be equipped for the irradiation of large objects, while the fourth face will have three injection holes to be used for the production of special, short-lived radioisotopes.

Availability of the short-lived radioisotopes at the hospital site will make possible a much wider range of medical investigation into fundamental body processes than can now be conducted, according to the AEC.

Need for a medical reaction has developed over the past six years, during which time Brookhaven scientists have used the available research reactor for neutron capture therapy in some types of brain tumors. In this treatment, the patient is given an injection in the blood-stream of a substance such as boron, which has an unusual capacity to capture neutron particles. A stream of neutrons from the reactor is directed at the brain tumor at a time when the tumor is packed with the boron, and the tumorous tissue is destroyed by the reaction which occurs between the neutrons and this substance.

Employing thermal neutrons, the new medical reactor will produce a treatment beam having an intensity 50 times greater than that provided by the Brookhaven general research reactor and, thus, will insure wider medical application of neutrons and flexibility of treatment.

## Symposia, Courses, and Special Programs of Study

*Human Engineering.* Two conferences are to be held in conjunction with the 3rd International Automation Exposition. The first is to be sponsored by Manhattan College at the Hotel New Yorker and is called "Automation and Man." The second is sponsored by the Business School of

Fordham University, and is entitled, "Office Automation for Senior Officers." The dates are November 28–29.

*Data Logging.* A two-day symposium, November 7–8, will present a series of 12 papers evaluating "Automatic Data Logging Systems" from the viewpoints of management, labor, production, and finance. It is to be held at the Bellevue-Stratford Hotel, Philadelphia, Pa., concurrently with an equipment exhibit.

*Solar Furnace Design and Operation.* The Association for Applied Solar Energy, in conjunction with Stanford Research Institute, Arizona State Colllege, and the University of Arizona, will sponsor a two-day symposium on solar furnace design and operation. The theme of the session will be "Today's Tool for Tomorrow's Research." It is to be held January 21–22.

*Electron Microscope School.* Mount Vernon, N. Y., will be the locale of the 2nd Norelco Electron Microscope School which will be held during the week of November 26–30 at the offices of the Instruments Division of the North American Philips Company, Inc., 750 S. Fulton Ave. Because of limited accommodations, attendance will be by invitation only. Those interested should write to C. J. Woods who will honor requests so far as space will allow. Registrants are urged to bring along micrographs and material they wish to discuss at the meetings.

*Enhancing Supervisory Skills and Executive Potential.* The University Extension of the University of California in the northern area is offering a Business and Management Program for Technical Personnel which will be an integrated program of business management subjects for those trained in engineering or other technical fields as they prepared to assume broader responsibilities in the firm. The classes are scheduled for late afternoon and early evening once a week for 18 consecutive weeks. There is a fee, and the sessions start in February.

*Advanced Science Program.* Hughes Aircraft Company has started a program to award fellowships to research personnel in its employ for advanced science study leading to doctoral degrees. The program was initiated in order to aid in the reduction of the nation-wide shortage of scientists and engineers. Three schools to which Hughes personnel will be sent are: University of Southern California, University of California at Los Angeles, and the California Institute of Technology.

*Mechanical Reliability.* A symposium sponsored by RETMA December 19–20 will feature sessions on mechanical reliability, information feedback, component evaluation usage, and other challenging discussions.

*Nuclear Power Station.* A two-day, five-session symposium on the design and construction of the first full-scale nuclear power station will be held in London, England, November 22–23.

*Truck Servicing.* A program to familiarize mechanics with the dramatic engineering advances in General Motors Corporation trucks as well as to school them on the latest servicing techniques has been turning out skilled truck maintenance specialists for the last three years. It is designed to teach truck maintenance, to keep top operating efficiency, and to service trucks properly. Training centers are located in key cities in 23 states and the District of Columbia.

## Armed Forces Branches Report on Several Developments

*Runway Profile Device.* Some of the hardest punches airplanes take come on the ground. Aircraft face one of the toughest structural tests when they taxi out on a runway for a takeoff.

The roughness inherent in present runways set up vibrations which tend to tear the heavy and flexible airplanes apart, when they taxi at high speeds in taking off from the field.

The new device, developed at Wright Air Development Center (WADC), may alter the situation. The development is a vehicle that takes a statistical picture of the runway —an actual profile. The information it provides can be related directly to what already is known about aircraft vibrations. Fortified with this information, Air Research and Development Command (ARDC) engineers will now be able to design aircraft with maximum performance capabilities and still provide for longer durability and usefulness.

The runway profile device has a fixed beam of high intensity light four inches in diameter created by a zirconium arc which is projected the length of the runway from a stationary unit. A recording vehicle is towed along this beam. A set of photoelectric cells in the vehicle locks onto the light beam and rides it to the far end of the runway. Every one-half foot along this course, a magnetic tape recorder charts the vertical distance from the beam of light to the runway surface, thus producing the profile of the runway. The statistics are then reduced to a simplified series of numbers, fed into a computer, and transformed into a curve which is actually a plot of runway power vs frequency. An aircraft's response to these frequencies of vibration is known.

*Pikes Peak Expedition.* A scientific expedition sponsored by the ARDC is currently making infrared radiation measurements from Pikes Peak and the adjoining Colorado area.

The joint United States Air Force, Army, and Navy team of some 160 technicians and assistants are measuring radiations from various types of military targets in an effort to establish techniques for distinguishing the targets from their backgrounds.

Infrared, an invisible part of the electromagnetic spectrum, and primarily associated with the emission of heat rather than light, has numerous military uses in missile guidance, reconnaissance, warning, aircraft defense, and fire control.

*World-Circling Air Force Scientific Expedition.* Air Force Cambridge Research Center (AFCRC) scientist accompanying a specially selected crew from the Strategic Air Command's Second Air Force will airlift a 1,500 pound cosmic ray monitor around the world, seeking important scientific data on cosmic radiation. It will detect radiation that enters the earth's atmosphere from outer space.

Careful measurements of the intensity of the incoming cosmic ray particles will enable AFCRC scientist to learn more about the orientation of the earth's outer magnetic field.

*Air from Outer Space.* Army Signal Corps scientists have captured six bottles of air from outer space. These are the only existing samples of pure air from very high altitudes of the upper atmosphere. The scientists from the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., expect to unravel basic mysteries in rocketry and geophysics. New tests on the gases could pave the way for flights of future missiles, manmade moons, and even space ships, all of which must pass at high speeds through such high altitude air.

The samples were collected 75 miles up by steel bottles inside the nose cones of two 20-foot U.S. Navy *Aerobee* rockets launched from the White Sands Proving Ground, N. M. The six special space bottles popped open one at a time as the rockets reached peak altitude, then snapped shut, each trapping eight quarts of the very thin air.

*Automation Devices for Bacteriologists.* In a two-pronged attack on a problem that has previously defied solution, a new instrument and a new system for the automatic counting of bacterial colonies, which will relieve bacteriologists of one of their more tedious and time-consuming tasks, has been developed at the Army Chemical Corps Laboratories, Fort Detrick, Frederick, Md.

The device functions by scanning the surface of the incubated Petri plate with a minute ray or "pencil" of light from a cathode ray tube, much as in the picture tube of a home television set. The ray moves across the Petri dish 1,000 times per second, completely scanning the agar surface by advancing 0.0035 inches for each line of scan. Changes in optical density between the transparent agar and the opaque colonies are recognized by a multiplier phototube.

The operating secret of the device lies in the action of its "memory" made of a quartz ultrasonic delay line which keeps track of the details of the previous tour of the scanning pencil across the dish in relation to its current scan. Electronic circuits compare these two records to determine which colonies are being encountered for the first time. Each new colony is counted in the registers of the machine. Repeated scans of the previously recognized colony are cancelled out by the comparing circuits, and hence not counted.

The alternative system, based on the conventional "dilution tube" procedure, is designed to avoid the electronic complications of the Automatic Colony Counter, but involves a rearrangement of the bacteriological laboratory steps. It is called the Automatic Microculture Counter. The sharply limited number of bacteriological test tubes ordinarily employed is avoided by substituting 994 tiny holes in a plastic "strip" about seven inches long, one inch wide, and one-eighth inch thick. Each strip has two one-eighth inch "rails" on one side. Thus, strips may be stacked in a magazine without the surfaces coming into contact. Dipped into a bacterial culture, the holes fill with the liquid. The charged strips are then incubated in a safety-approved container for the same period as is the Petri plate. Holes which happen to have originally received one or more bacteria become iridescent through bacterial proliferation; the sterile holes remain clear. After incubation, the strips are photographed one by one, while still in the container, with an automatic camera specially developed for this purpose. The film of the strips is then passed through a modified film reader which gives a sequence of electrical pulses equal in number to the number of sterile holes in the plastic strip. Totaled pulses are converted to punched card code, automatically punched into a card, and later processed in an electronic computer.

*Microwave Relay System.* The use of micro-

wave equipment for the relaying of radar information was demonstrated recently at the Rome Air Development Center (RADC), Griffis Air Force Base, Rome, N. Y.

Following a talk on the "Present and Future Status of Military Microwave," the demonstration itself consisted of a showing of two PPI radar indicators; one operating directly from a search radar, the other receiving its input from a two-hop microwave system totaling some 24 miles in length. Comparison was impossible because there was no way of distinguishing between the two displays.

Utilization of such a system in the near future will provide information on the direction and height of planes, formation of clouds, and the movement of tornados and hurricanes.

Thus, this RADC developed system will enable the use of unattended radar units to relay information from remote terrain instantaneously. It will tie in with an existing microwave network and will be expanded to obtain data from widespread areas.

The United States Weather Bureau is also interested in such a setup because it would permit more rapid and accurate determination of weather trends and hurricane and tornado tracking.

*Inventive Talent To Solve Defense Problems.* The National Inventors Council (NIC) of the United States Department of Commerce has declared that if a person is a professional or amateur inventor with the germ of an idea at the back of his or her mind, it should be developed. The idea and its implementation may be the solution to one of the technical problems currently affecting national defense. Many civilian inventors have contributed brainpower toward the solution of Armed Forces problems which have saved many lives and much money.

The NIC publishes a cumulative list of technical problems turned over to it and, since 1940, has served as a liaison agency between inventors and the Armed Forces. The current copy of "Technical Problems Affecting National Defense" can be obtained by writing to NIC, U.S. Department of Commerce, Washington 25, D.C.

## Machine Sprouts Grass for Livestocks' Dinner Menu

It was bound to happen—that even Mother Nature would begin to feel the impact of automation: A Texas firm is producing automatic grass-growing machines.

The purpose of this man-made creation is to provide fresh, nourishing forage for livestock the year-round. The machine, called a "Herbagere" (invented by a Belgian), transforms grain into grass six to seven and a half inches high, in six days.

The unit itself is a metal-framed box with seven drawers or "stages." In the top drawer, water is mixed with a special chemical formula. This feeds down to the lower stages. Perforated baskets holding 6 or 7 pounds of seed occupy the drawers.

Temperature control, a critical factor in growing the grass, is achieved through automatic control of electric heating elements. A special control unit regulates flow of electricity, thus automatically maintaining the precise temperature required. Different seeds need different temperatures.

During operation the grains and growing shoots are automatically irrigated daily with a solution containing dissolved nutrients. This eliminates the need for soil.

A single, seven-drawer machine can produce forage enough for 10 cows. Or looking at it another way, 50 pounds of pregerminated seed can produce, daily, 300 to 360 pounds of man-made grass.

Oats, wheat, barley and other common seeds can be grown in the machine without any difficulty.

Increase in milk and butterfat production, savings in feed costs and all-around better health for livestock are cited as expected benefits of the man-made feed.

# NEW BOOKS

**The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.**

ABACS OR NOMOGRAMS. By A. Giet. Philosophical Library, Inc., 15 East 40th St., New York 16, N. Y., 1956. 225 pages, 5½ by 8¾ inches, bound. $12. This book demonstrates, for practicing engineers, how nomograms may be constructed without highly specialized mathematical knowledge. The subject matter is presented in five parts covering the relations between two variables, Cartesian abacs, alignment charts based on parallel co-ordinates, alignment charts not based on parallel co-ordinates, and relations between *n* variables. The French units of the original have, in some cases, been converted to British units, and conversion factors are included for numerical examples.

ASTM STANDARDS ON ELECTRICAL INSULATING MATERIALS (1956) Published annually by the American Society for Testing Materials (ASTM), 1916 Race St., Philadelphia 3, Pa. 642 pages, 6 by 8⅞ inches, paper. $6. A compilation of 83 standards covering insulating shellac and varnish, ceramics products fabrics and papers, mica products, filling and treating papers, mica products, filling and treating compounds, mineral oils, plastics, etc. A number of electrical tests and conditioning requirements for testing are also included.

BIBLIOGRAPHIC SURVEY OF CORROSION 1952–1953. Publication No. 56-11. Published 1956 by National Association of Corrosion Engineers, 1061 M and M Building, Houston 2, Tex. 382 pages, 8½ by 11¼ inches, bound. $12.50. Summaries of over 3,000 references on corrosion and corrosion prevention are arranged in the following main groups: general, testing, characteristic phenomena, corrosive environments, preventive measures, materials of construction, equipment, and industries. The references are indexed by subjects and by authors. An appendix has been included to aid the user in locating and obtaining copies of foreign or domestic journals or articles.

DIGITAL DIFFERENTIAL ANALYZERS. An Applications Manual for Digital and Bush-Type Differential Analyzers. By G. S. Forbes. Published by George F. Forbes, 10117 Bartee Ave., Pacoima, Calif. third edition, 1956. 154 pages, 8½ by 10¾ inches, paper. $7.50. Added to this edition are over 100 pages of new material covering trajectory problems, simultaneous algebraic equations, partial differential equations, complex functions, conformal mapping, etc. The first part of the manual, a reprint of the second edition, shows the basic integrator mechanisms for the generation of exponential trigonometric, algebraic, and inverse trigonometric functions, and discusses adders and servos and their uses. Diagrams are used throughout to show the setting up of the various operations, and exercises are included.

DYNAMIC FACTORS IN INDUSTRIAL PRODUCTIVITY. By Seymour Melman. John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1956. 238 pages, 5½ by 8¼ inches, bound. $4.75. This is an investigation, based on British and American experience, of the effects on manufacturing productivity of the relative cost of man-hours and machine-hours, and of the rise of administrative overhead. The study includes a chapter on engineering implications which shows how the changing relation of the costs of men and machines can be taken into account in the design of production facilities.

ELECTRONIC MEASURMENTS AND MEASURING INSTRUMENTS. By F. G. Spreadbury. Essential Books, Inc., 16–00 Pollitt Dr., Fair Lawn, N. J., 1956. 459 pages, 5⅜ by 8½ inches, bound. $8. This work is devoted to describing fully certain basic types of instruments: voltmeters, ammeters, wattmeters stroboscopes, cathode-ray oscillographs, photoelectric cells, etc. Instruments for frequency and time measurement, electron optical systems, and a-c bridges are also covered, and consideration is given to tube characteristics, auxiliary apparatus, power supply, and construction practice.

ENGINEERING AS A CAREER. By R. J. Smith. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N. Y., 1956. 365 pages, 5⅜ by 9¼ inches, bound. $4.75. This book introduces the beginning engineering student to the nature of the profession, to the type of studies in which he will be engaged during his four years of college, and to selected topics in civil, electrical, and mechanical engineering. The qualifications, duties, and responsibilities of the engineer are indicated, and the profession is described both in terms of the major branches and in terms of functions—research, design, construction, management, etc. Materials, mechanics, thermodynamics, electrodynamics, and engineering economy are the engineering subjects introduced.

EVALUATION OF INSULATING OILS—EUROPEAN DEVELOPMENTS. (Special Technical Publication No. 172.) Published 1956 by the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. 72 pages, 6 by 8⅞ inches, paper. $1.75. Research in Sweden, France, and England on the testing of insulating oils is reported in the following three papers included in this publication: Catalysts for Accelerated Testing of Transformer Oil, The Performance Characteristics of Used Insulating Oil, and The Evaluation of Inhibited Transformer Oils. Discussion of the papers is also included.

THE GENERATION OF ELECTRICITY BY WIND POWER. By E. W. Golding. Philosophical Library, Inc., 15 East 40th St., New York 16, N. Y., 1956. 318 pages, 5½ by 8¾ inches, bound. $12. This account of recent research and development work on the use of wind power on a significant scale is divided, roughly, into three parts. Part one is devoted to wind behavior and its determination: wind distribution, measurement of velocity, energy estimation, and the selection of sites for wind power units. The remaining two parts deal, respectively, with types of wind driven machines and generators and with economic considerations. In addition to chapter bibliographies, a bibliography on surface wind data, is included. A glossary of French, German, and English terms is appended.

LINEAR TRANSIENT ANALYSIS. Volume II. Two-Terminal-Pair Networks Transmission Lines. By Ernst Weber. John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1956, 452 pages, 5⅞ by 9¼ inches, bound. $10.50. In this text for graduate students, the Fourier and Laplace transform methods (reviewed in the first chapter) are applied to the analysis of transient phenomena in passive and active two-terminal-pair networks, in filters, and in transmission lines. The book includes an extensive discussion of the application of the Fourier transform method in the idealization of the network characteristic and a careful development of the traveling wave concept.

NUCLEAR FUELS. By D. H. Gurinsky and G. J. Dienes. (The Geneva Series on the Peaceful Uses of Atomic Energy.) D. Van Nostrand Company, Inc., 120 Alexander St., Princeton, N. J., 1956. 364 pages, 6 by 9¼ inches, bound. $7.50. This is one of a series of six volumes made up of edited and integrated selections from papers delivered at the International Conference on the Peaceful Uses of Atomic Energy. The present volume, intended as an introduction to the subject, gives basic information on the metallurgy of uranium and thorium, the problem of radiation, and specific fuel systems using solid and fluid fuels.

NUMERICAL ANALYSIS. Proceedings of Symposia in Applied Mathematics of the American Mathematical Society, Volume VI. McGraw-Hill Book Company, 330 West 42nd St., New York 36, N. Y., 1956. 303 pages, 6¾ by 10½ inches, bound. $9.75. Among the topics covered in the 19 papers which comprise

this volume are the theory of dynamic programming, boundary valve problems, combinatorial problems, shock configuration in Mach reflection, applications of gradient methods, approximations in numerical analysis, the method of steepest descent, and the solution of linear systems by iteration.

THE PETROLEUM REFINERY ENGINEER'S HANDBOOK. By J. F. Strachan. Philosophical Library, Inc., 15 East 40th St., New York 16, N. Y., 1956. 168 pages, 7⅞ by 10 inches, bound. $15. Despite its inclusive title this is a manual for those responsible for the inspection and safety of refinery equipment. The first two chapters deal with the organization, personnel, and records of the inspection department and with inspection procedures for the various refinery processes. The remaining three chapters are concerned with corrosion and protective measures, formulas for calculating the strength of pipes and vessels, and general safety measures.

PROGRESS IN NUCLEAR ENERGY. Series I—Physics and Mathematics. Volume 1. Edited by R. A. Charpie and others. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N. Y., 1956. 398 pages, 6 by 9¼ inches, bound. $12. This volume contains critical summaries of data on fission physics made available at the International Conference on the Peaceful Uses of Atomic Energy. Of the 12 papers included, four deal with the following subjects in basic reactor physics: homogeneous critical assemblies, zero energy studies on fast reactors, heterogeneous methods of reactor calculations, and theory and experiment of highly enriched intermediate and thermal assemblies. Other papers deal with neutron scattering and absorption, properties of fissionable materials under neutron bombardment, and delayed neutrons.

SCHEDULING OF PETROLEUM REFINERY OPERATIONS. By A. S. Manne. Harvard University Press, Cambridge 38, Mass., 1956. 185 pages, 5½ by 8½ inches, bound. $5. In this study, intended for petroleum engineers and economists, graphical methods, calculus, linear programming, and several types of nonlinear programming are used in the analysis of representative scheduling problems. The operations discussed are the allocation of crude oils to refineries at different locations; naphtha reforming; gasoline blending; and scheduling for a small plant in which cracking, recycling, and blending are integrated. The book also includes a brief review of conventional refinery economic analysis.

SURGES ON TRANSMISSION SYSTEMS. By Shigenori Hayashi. Denki-Shoin, Inc., Kyoto, Japan, first edition, 1955. Available in the United States from the Charles E. Tuttle Company, Rutland, Vt. 355 pages, 7⅛ by 10¼ inches, bound. $12. This new work brings together in compact and available form the modern mathematical theories of traveling wave phenomena in electric transmission systems. Particular attention is paid to specialized aspects of the field, and the major part of the book is devoted to a new analytical method devised by the author for dealing with traveling waves on multiconductor systems. Rigorously presented, the method makes possible the solution of certain complex problems both in laboratory research and in practical operation.

## PAMPHLETS

**The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.**

THE ISOTOPE INDEX. The first up-to-date, complete guide to the isotopes. This unique 64-page book lists the source of every known commercially available isotope. Included are both stable and radioactive isotopes and hundreds of isotope-labeled compounds of C-14, I-131, P-32, S-35, Deuterium, etc. More than 2,000 different items in all from the more than 40 United States and Canadian suppliers. Complete purchasing information supplied including chemical name or formula, specific activity, interfering activities, supplier, supplier catalogue number, and latest published price. Also included for each isotope is its half life and principle radiation. In addition, the index includes sections on the available calibration samples, radiographic and therapeutic sources, a complete list of the known suppliers, and a brief section on the recently revised Atomic Energy Commission license requirements. An invaluable book for anyone using or purchasing isotopes. Available from stock at $2 per copy in the United States and Canada ($2.50 Foreign); sent postpaid. Please send remittance with order to Publications Department, Scientific Equipment Corporation, 23 N. Hawthorne Lane, Indianapolis 19, Ind.

THE PROCEEDINGS OF THE SYMPOSIUM ON EARTH SATELLITES AS RESEARCH VEHICLES. Under the auspices of its Journal, The Franklin Institute has published the full proceedings (including discussions) of the Earth Satellite Symposium held in its Lecture Hall on April 18, 1956, as Monograph No. 2 in the *Journal* series. Containing seven papers by outstanding authorities in various phases of the earth-satellite program, the Monograph presents a scientific approach to the problems involved in placing an artificial satellite in an orbit and discusses the problems which may be solved with a successful launching. $2.50 per copy from *Journal* of The Franklin Institute, 20th and the Parkway, Philadelphia 3, Pa.

RCA MAGNETRONS AND TRAVELING-WAVE TUBES. Published by Tube Division, Radio Corporation of America (RCA), Harrison, N. J. This 40-page booklet contains basic information on the features and applications of these microwave devices. Prepared to assist those who work with microwave tubes and circuits, it describes the theory of operation of magnetrons and traveling-wave tubes, presents operating considerations and applications, and gives techniques for measurement of important electrical parameters. Illustrations included show structural parts of both types of tubes, typical performance characteristics, test methods, and representative circuit applications. Data are given for four commercially available RCA magnetrons and one traveling-wave tube. An extensive list of references also is included. The booklet *MT-301* may be obtained by sending 50 ¢ direct to Commercial Engineering, RCA Tube Division, Harrison, N. J.

HANDBOOK OF SEMICONDUCTOR ELECTRONICS. 832 pages, illustrated, $12. Under the editorship of L. P. Hunter, senior physicist of the International Business Machines (IBM) Corporation, 13 specialists, representing leading manufacturers and users of semiconductor devices, have produced this handbook covering physics, technology, and circuit applications of transistors, diodes, and photocells. After briefly describing transistor action, the book explains basic physics of electrical conduction in solids as a background for understanding mechanisms of transistor and diode action. Technological processes used in transistor and diode fabrication also are surveyed. This includes basic processes and techniques commonly used and how they achieve satisfactory device performance. Enough information is given to enable anyone to design and produce a satisfactory semiconductor device of average characteristics. A large part of the book is devoted to circuit design and applications, as well as the subjects of low- and high-frequency amplifiers and switching circuits; directly coupled amplifiers; transistor oscillators; and circuits using special semiconductor devices. Sufficient background material is supplied to make unnecessary to consult outside references in order to understand the main body of text. Further details are available from McGraw-Hill Book Information Service, 327 W. 41st St., New York, N. Y.

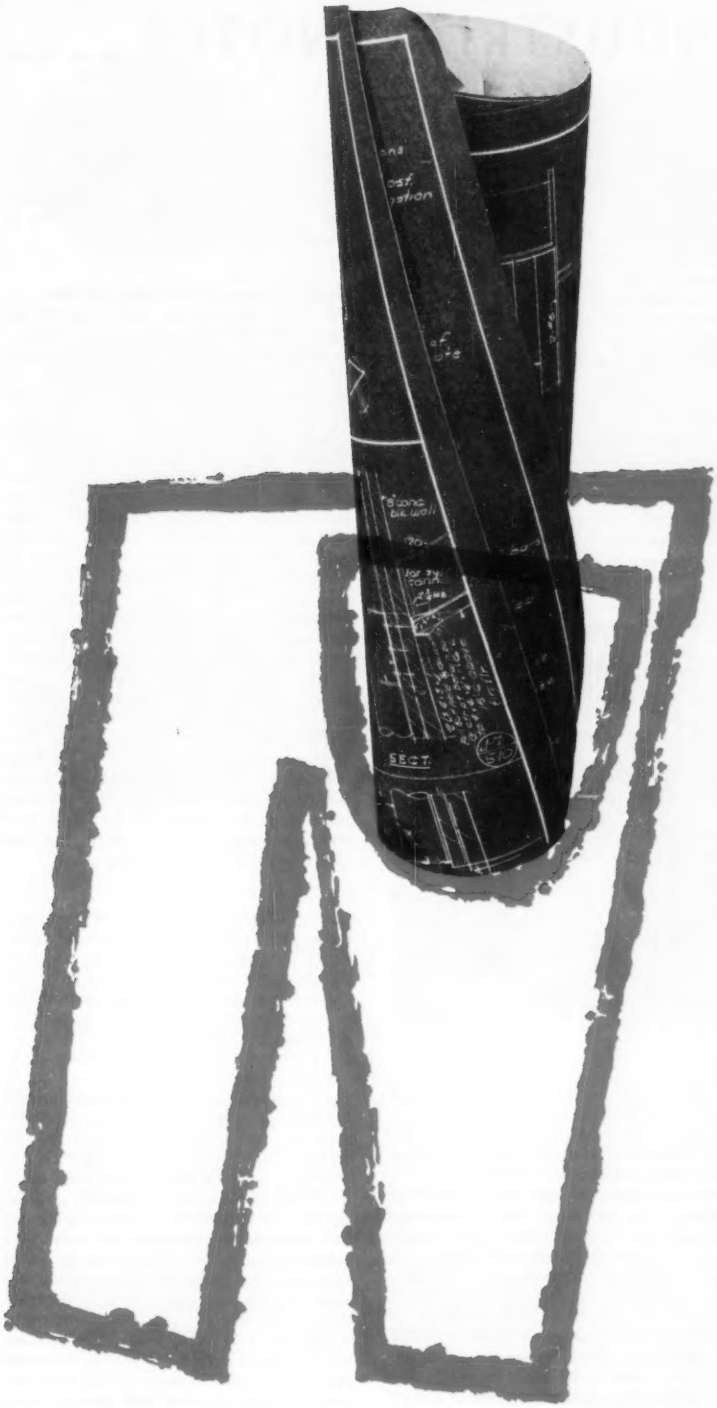
LIGHTING FOR COMMERCIAL KITCHENS. This report covers all phases of lighting for food handling and preparation in restaurants and other institutional kitchens from delivery of foodstuffs, through storage, inspection, cooking, serving, and pricing. It emphasizes the wide variety of seeing tasks, critical and general, encountered in such kitchens. The lighting for each operation is analyzed, sanitary conditions and speed being of prime consideration. The report includes recommended lighting levels; brightness ratios; reflectances of walls, ceilings, and floors; and selection of types of fixtures providing ease of maintenance as well as proper illumination characteristics. This 8-page report, concise and fully illustrated, is of value to owners, architects, lighting and consulting engineers, electrical contractors, and others. Copies may be obtained from Publications Office, Illuminating Engineering Society, 1860 Broadway, New York N. Y., for 15¢ each. Quantity prices on request.

RESISTANCE WELDING—THEORY AND USE. Contains material gathered by the American Welding Society Resistance Welding Committee on every aspect of the resistance welding processes and their use in welding different metals for applications in every kind of industry (automotive, aircraft, railroad equipment, refrigeration, radio, television, metal parts manufacture, etc.). The most significant feature of the book is that for the first time resistance welding is presented in clear, everyday language so it can be understood without previous knowledge of welding. Yet, the subject is so thoroughly covered and so authoritative and up to date that it will interest welding engineers, metallurgists, designers, and shop personnel. Included are full details of the six resistance-welding processes, machines, controls and electrodes, welding of different metals, weld quality, inspection, and testing. Published by the Reinhold Publishing Corporation, 430 Park Avenue, New York 22, N. Y. at a price of $4.50.

THIN FILMS OF POLYTETRAFLUOROETHYLENE RESIN (TEFLON) AS LUBRICANTS AND PRESERVATIVE COATINGS FOR METALS. Highly successful use of Teflon (polytetrafluoroethylene resin) for lubricating and preserving a wide variety of military equipment is described in a Navy report available to industry through the Office of Technical Services (OTS), U. S. Department of Commerce. Applied as a thin film to hard substances, Teflon produces a dry, chemically resistant, all-weather lubricant. Its preservative qualities are described as remarkable by the Naval Research Laboratory (NRL), which pioneered use of the coating. The report summarizes experimental work and field tests on a number of applications of Teflon to guns and ammunition, submarines, aircraft, and other equipment. An appendix contains a number of essential techniques developed by NRL which insure minimum friction, maximum durability, good adhesion, and good corrosion-prevention properties. Teflon is not a panacea for solving all lubricating problems without the use of oils and greases, the report points out. However, when properly used the coating is ideal in numerous applications of value to both the military and industry. The report, *PB 121161*, V. G. Fritz-Simmons and W. A. Zisman, NRL, June 1956, may be ordered from OTC, U. S. Department of Commerce, Washington 25, D. C. It contains 32 pages, price $1.

ELECTRONICS DATA HANDBOOK. Released by Allied Radio Corporation, this 64-page handbook consists of a carefully selected collection of the most often needed formulas and data used in radio and industrial electronics. Formulas include those needed for basic circuit analysis, transmission line calculations, determination of vacuum tube characteristics, resonance calculations, meter calculations, etc. Included are up-to-date Radio-Electronic-Television Manufacturers Association (RETMA) and Military specifications for resistors and capacitors, coil winding data, wire gage data, metric relationships, tables for directly interchangeable radio and television picture tubes, interchangeable batteries, decimal equivalents of fractions, pilot lamps, logarithms, trigonometric functions, etc. A three-page explanation on the use of logarithms precedes the logarithm tables. Additional data covers attenuator networks; minimum loss pads, mixers; decibels vs voltage; current and power ratios; and complete details on using the RETMA 80.7-volt system of speaker hookup. This information has been compiled from the most authoritative text books and reference works, or has been prepared by Allied's technical staff. It is presented in an organized, easy-to-find form. Prepared by the Publications Division of Allied Radio, under the direction of Eugene Carrington, the handbook was edited by N. M. Cooke. The book *37K398* is available from Allied Radio Corporation, 100 N. Western Ave., Chicago 80, Ill,. and is priced at 35¢ postpaid.

1952–1953 BIBLIOGRAPHIC SURVEY OF CORROSION. Publication No. 56-11, 1956. Compiled by A. I. Humphrey. Summaries of 3,344 corrosion and corrosion prevention articles, books, and brochures published in 1952–1953 are compiled in this volume. Material was selected from bulletins published by more than 30 abstracting agencies representing international literature coverage. Abstracts are arranged topically according to the National Association of Corrosion Engineers (NACE) Abstract Filing Index. The Filing Index divides the literature into eight main groups: general, testing, characteristic corrosion phenomena, corrosive environments, preventive measures, materials of construction, equipment, and industries. Each main group is subdivided. Topical cross-references are appended to each section. The subject index also lists many metals and alloys by trade name and indexes them as to specific properties and to behavior in specific media. An author index is included. All referencing is to classification and serial numbers of abstracts for ease in searching. An appendix has been included to aid the user in locating and obtaining copies of unfamiliar foreign or domestic journals. This is the fifth in a series of NACE bibliographies on corrosion literature. The preceding four volumes, covering 1945 through 1951, contained 12,414 abstracts. 382 pages, $12.50 for nonmembers of NACE, $10.00 for members. Available from National Association of Corrosion Engineers, 1061 M & M Building, Houston 2, Tex.



# have an idea in your hip pocket?

Then we have an idea you'll be happiest at Firestone... where ideas are most likely to see the light of day and breathe the air of success. Here, too, you'll discover benefits and attitudes inspire more ideas, more success.

Ideas—and men with ideas—have kept Firestone at the top of the pioneers-in-progress list for 56 years. Right now, we're carrying forward the Army's vital program for the "Corporal," first surface-to-surface ballistic guided missile. This includes development engineering, field test and service, and missile and component production.

But the need for good men with good ideas grows... because Firestone plans to keep growing in this field. For instance, here are just a few specific needs—a few from a list too long to show in full:

*Component Design*
*Electronics Systems*
*Mechanical Systems*
*Flight Simulation*
*Field Engineering*

There's a man at Firestone with ideas—good ideas—on your future. Why not write today?

Firestone

**GUIDED MISSILE DIVISION**
RESEARCH • DEVELOPMENT • MANUFACTURE

*"Find your Future at Firestone"—Los Angeles • Monterey*
WRITE: SCIENTIFIC STAFF DIRECTOR, LOS ANGELES 54, CALIF.

# HOW
## to get the most for your electrical maintenance dollar

↯ Plan your own electrical maintenance facilities . . . layout —equipment—payroll . . . for minimum anticipated volume. Keep men and machines busy all the time.

↯ Send the jobs you can't handle without overtime to National for fast, high quality rewinding at economical prices.

↯ To assure top quality, reliability and economy in your own work, make National your first source for replacement coils and rewinding supplies.

↯ Confine your rewinding operations to the routine jobs. Big rotating electrical equipment is a job for specialists and special equipment which you can't economically support.

↯ Call National when you have a problem with a large or complicated motor or generator. We have the specialists—in engineering and production—and the special equipment to do the job right—working in our plant or yours.

No matter what industry you're in or where you're located, National can help you. Steel, mining, railroads, utilities—you name it and we'll cite cases to show how others in your position have found that they can stretch their electrical maintenance dollar by making National a part of their electrical maintenance team. See your nearby National field engineer or drop us a line for the complete story. Do it today.

TRADE NATIONAL COILS MARK

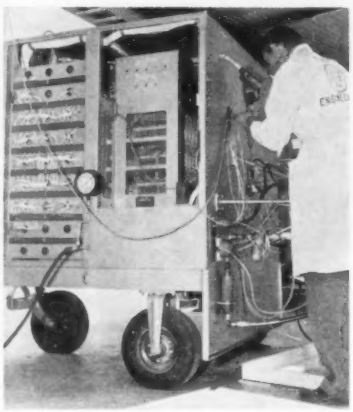
NATIONAL ELECTRIC COIL CO.

COLUMBUS 16, OHIO, U. S. A.

▲ Circle 9 on the card.


# INDUSTRIAL NOTES ....

**New Research and Development Center.** American Machine and Foundry Company's (AMF) Turbo Division has dedicated its new 66,000 square foot advanced research and development center, one of the most modern facilities in the United States for the development of accessory power supplies for guided missiles. The research and development center houses the administration, engineering, and drafting offices, research and test laboratories, technical library, and photographic facilities. The test areas are specially designed; each of the test cells consists of one or two test bays plus an adjacent blockhouse containing a central instrument console. Multiple, high-response recorder channels plug into the consoles from sensing devices mounted on each power supply. A significant departure from normal test-cell procedure is used in testing the accessory power



supplies. The unit to be tested, its fuel, and the sensing instruments are mounted on a mobile test cart. The unit remains on the cart throughout the test, thereby cutting down installation and removal time, and achieving more efficient use of the test facility. The laboratory also includes an environmental test chamber that duplicates the extremely destructive effects of high altitudes on accessory power supplies. The chamber can simulate atmospheric pressures at altitudes from sea-level to 100,000 feet and temperatures from −100F to +200F at relative humidities up to 100 per cent. Also to be built by AMF is a new plant for a Canadian atomic energy contract. AMF Atomic (Canada) Limited, a subsidiary of AMF, will build a 30,000 square foot plant on a 30-acre site at Port Hope, Ont., to carry out the contract. This will be the first unit of a large nuclear facility. AMF Atomics (Canada) is the first private company in Canada to be organized solely for nuclear research, development, and engineering. In addition to fabricating fuel elements, the plant will have a nuclear laboratory to conduct engineering, research, development on research and power reactors and their components and auxiliaries. The laboratory also will provide engineering services to outside organizations.

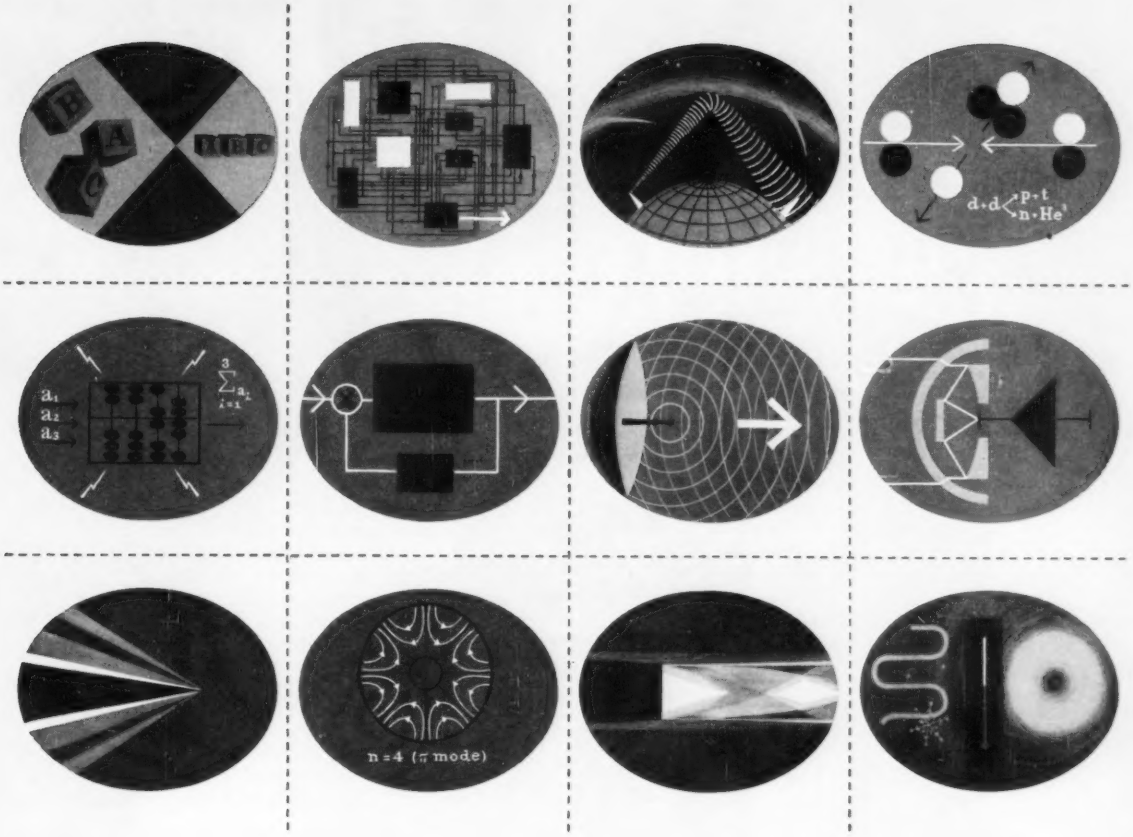
**Radar Beacon for Guided Missiles.** A miniature, lightweight radar beacon designed to enable ground crews to track a guided missile in flight has been developed by Radio Receptor Company, Inc., of Brooklyn, N. Y. Although it weighs only $2^1/_2$ pounds and is roughly the size of a jelly jar, the new device, called the Radar Beacon, *AN/DPN-43* is rugged enough to withstand the terrific shocks and temperature variations of missile flight. The new beacon's job is to receive and return radio signals monitored at a ground tracking point. Its entire service life is only 30 minutes or so, but it is designed for utmost reliability. Weight, space, and reliability considerations required the use of transistors instead of tubes. More than 120 components have been squeezed into its 6-inch height and $2^1/_2$-inch diameter. The beacon, which was developed for the Evans Sigi al Laboratory of the Army's Signal Corps Engineering Laboratories at Fort Monmouth, N. J., consists of three main assemblies: a tiny 6-volt battery, a tuned preselector with a high-gain crystal-video receiver, and a modulator driving a low-power transmitter-tuned cavity that can emit a watt or more of output power.

**Name Change.** The Waterbury Brass Goods Division of The American Brass Company officially changed its name to Fabricated Metal Goods Division. This division manufactures specialities from flat or sheet metal, particularly products of small size and close tolerance.

**Service Plan for Scientific Instruments.** Scientific instrument users can now obtain a service and repair policy similar to the coverage purchased by many television set owners. Under a plan announced August 24, Chicago Apparatus Company, supplier of scientific equipment, will perform regular preventative maintenance and make immediate emergency repairs at no extra charge to the customer. The plan is designed to provide protection against breakdowns of highly complex apparatus. Under the new plan, periodic inspections of equipment will be made by Chicago Apparatus representatives who have undergone intensive training and been certified by instrument manufacturers. In addition, emergency work will be performed immediately.

**Recording Oscillograph.** Explosionproofing for airborne applications and a flash timing system for absolute synchronization of multiple oscillograph installations are

(*Continued on page 38A*)




# Variety of Technical Fields

These illustrations are symbolic of some of the scientific and engineering fields of endeavor which are essential ingredients in the broad range of technical programs that are in progress at The Ramo-Wooldridge Corporation. Illustrated are: Information Theory, Systems Analysis, Communications, Nuclear Physics, Electronic Computers, Servomechanisms, Electromagnetic Propagation, Infrared, Aerodynamics, Microwaves, Propulsion, and Thermodynamics.

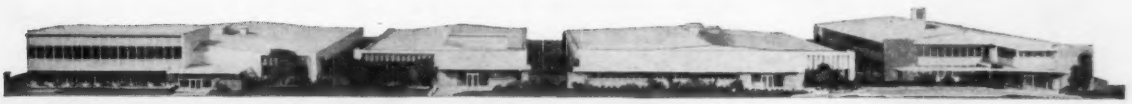
The requirement for technical competence in a wide variety of fields is a significant characteristic of systems engineering work. At R-W this requirement is particularly important because of our emphasis on the development of systems having a high content of scientific and engineering newness.

Our current military contracts support a number of advanced programs in the fields of modern communications, digital computing and data processing, fire control and navigation systems, instrumentation and test equipment. In the guided missile field, Ramo-Wooldridge has technical direction and systems engineering responsibility for the Air Force Intercontinental and Intermediate Range Ballistic Missiles. Our commercial contracts are in the fields of operations research, automation, and data processing. All of this work is strengthened by a supporting program of basic electronic and aeronautical research.

*Scientists and engineers whose training and experience are in these or related fields are invited to explore the openings at The Ramo-Wooldridge Corporation.*

## The Ramo-Wooldridge Corporation

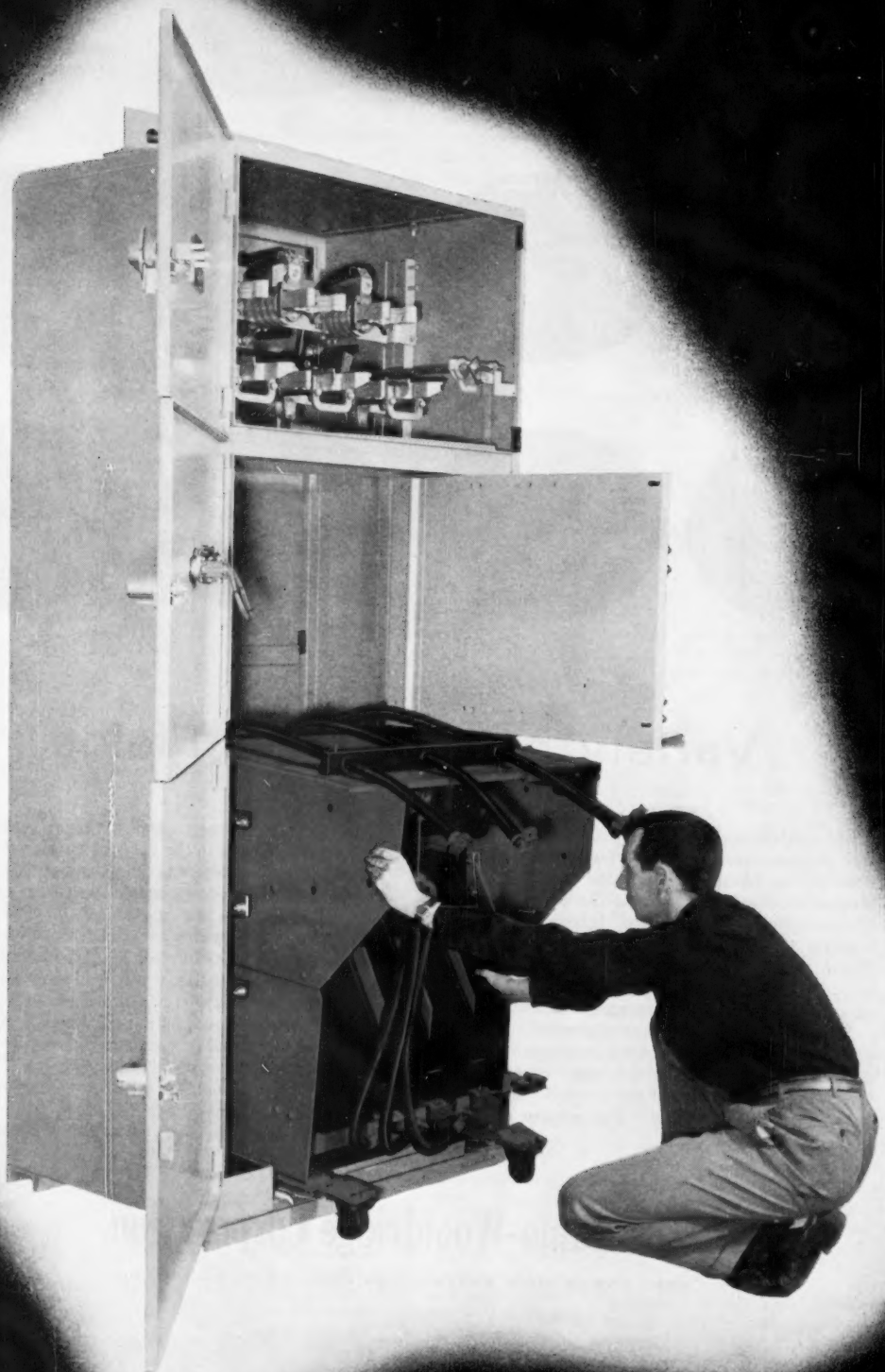
5730 ARBOR VITAE STREET · LOS ANGELES 45, CALIFORNIA





Circle 10 ▶

# HIGH-VOLTAGE MOTOR CONTROL.....



...LEADER IN DESIGN AND PERFORMANCE

# GENERAL ELECTRIC LIMITAMP* STARTERS OFFER ROLL-OUT CONTACTOR UNITS FOR EASIER INSTALLATION

Today's General Electric Limitamp starters are designed to bring you the utmost in installation ease, speed, and economy.

Key feature of this cost-cutting design is the caster-mounted contactor unit which can be easily rolled into or out of the Limitamp enclosure. After swinging out the hinge-mounted low-voltage panel, and before rolling in the contactor unit, the installation man can walk right inside the enclosure to make connections quickly and conveniently.

Once connections are completed, the panel can be closed and ready to operate within seconds. Limitamp panels control and protect motors rated 2300 to 4800 volts and ranging up to 3000 horsepower.

## MORE LIMITAMP CONTROL FEATURES

Fast, economical installation is but one benefit of General Electric Limitamp control. There are many more. For instance:

- Five-square-foot saving of floor space through use of higher-capacity fuses to eliminate need for an extra fuse cabinet.
- Increased personnel safety provided by three-phase disconnect switch.
- Flexible arrangement of units and added space savings, with all connections made from front.
- Complete range of modifications to meet any installation requirement.

## REALIZE THESE BENEFITS NOW

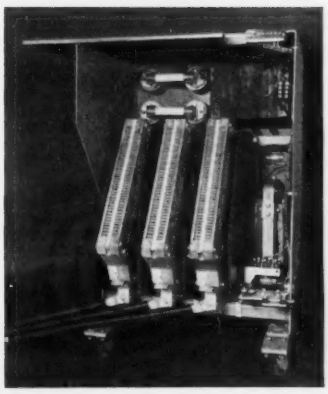
Don't be satisfied with "old-fashioned" high-voltage motor control: Specify General Electric's Limitamp control—*leader in design and performance*. Contact your G-E Apparatus Sales Office today, or write Section 783-2, General Electric Company, Schenectady, New York.

*Industry Control Department, Roanoke, Virginia.*

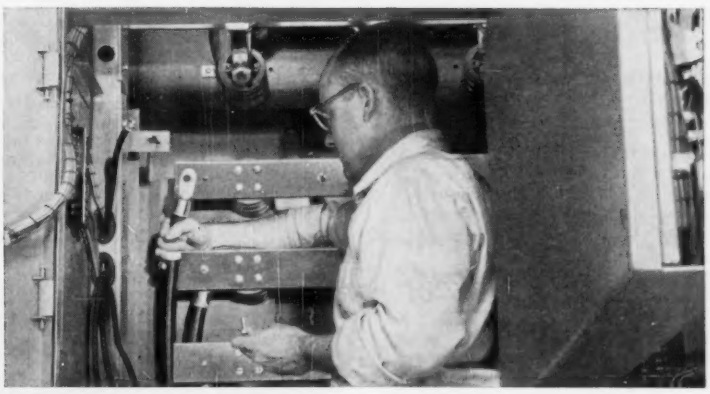
*Reg. Trade-mark of General Electric Company.

*Progress Is Our Most Important Product*

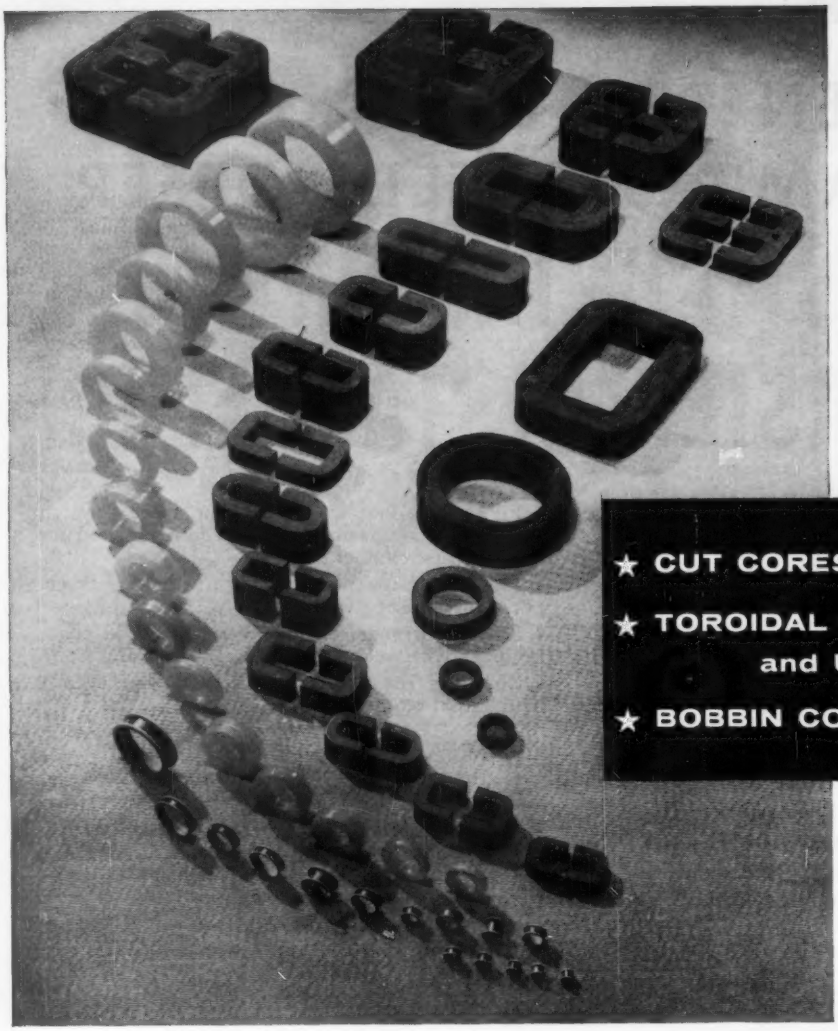
GENERAL ELECTRIC



**MAINTENANCE EASY** on contactor; generally devices are front-removed.



**THERE'S AMPLE SPACE** to stand inside enclosure and make necessary connections. Yet entire control requires 50% less floor space than before.



★ CUT CORES, Types C and E

★ TOROIDAL CORES, Cased and Uncased

★ BOBBIN CORES

# It's ARNOLD for EVERYTHING in TAPE-WOUND CORES

## *Applications*

Let us help you with your core requirements for Pulse and Power Transformers, 3-Phase Transformers, Magnetic Amplifiers, Current Transformers, Wide-Band Transformers, Non-Linear Retard Coils, Reactors, Coincident Current Matrix Systems, Static Magnetic Memory Elements, Harmonic Generators, etc.

## *For Complete Details*

**Write for Bulletins:**

★ SC-107—Cut Cores, Types C and E
★ TC-101A—Toroidal Cores, cased and uncased
★ TC-108—Bobbin Cores

**ADDRESS DEPT. EL-611.**

*MATERIALS:* Deltamax, 4-79 Mo-Permalloy, Supermalloy, Mumetal, 4750, Monimax, Silectron, Permendur: all are available for cores depending upon the specific properties required.

*GAUGES:* The following standard tape thicknesses are available for Arnold tape wound cores in most of the magnetic materials mentioned above: .012", .004", .002", .001", .0005", or .00025". Bobbin cores are made from tape .001" to .000125" thick.

*SIZES:* Cores weighing from a fraction of a gram to many hundreds of pounds can be supplied. Toroidal cores are made in 27 standard sizes with nylon cases. Types "C" and "E" cut cores are made in a total of 530 standard sizes. Many special sizes and shapes of both gapless and cut cores are manufactured for unusual requirements.

*OTHER PRODUCTS:* In addition to Tape-Wound Cores, we also produce a complete line of Mo-Permalloy Powder Cores, Iron Powder Cores, and permanent magnets. • *Let us work with you.*

WSW 5816 B

**THE ARNOLD ENGINEERING COMPANY**

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

**Main Office & Plant: Marengo, Illinois**

Repath Pacific Division Plant: 641 East 61st Street, Los Angeles, Calif.

*District Sales Offices:*

New York: 350 Fifth Ave. Los Angeles: 3450 Wilshire Blvd. Boston: 200 Berkeley St.



For more information circle 11 on reader service card.

Wire Sculpture by Henry Szafarz

## It's Another World . . .

one in which the forces of nature are extremely rough on man-made things. Thus, the simple fact that Simplex supplies more submarine cable than all other manufacturers combined speaks volumes as to product quality. Simplex Submarine Cables are specifically engineered for reliable underwater communication and power transmission. Their many varieties of outer coverings, wire armor, heavy jackets of Neoprene and other materials, guard against underwater hazards and assure long, dependable service.

**SIMPLEX WIRE & CABLE CO.,**
79 Sidney Street,
Cambridge 39, Mass.

Photo of Transoceanic Telephone Cable, Cut Back to Show Construction

LIVE BETTER ELECTRICALLY

Simplex



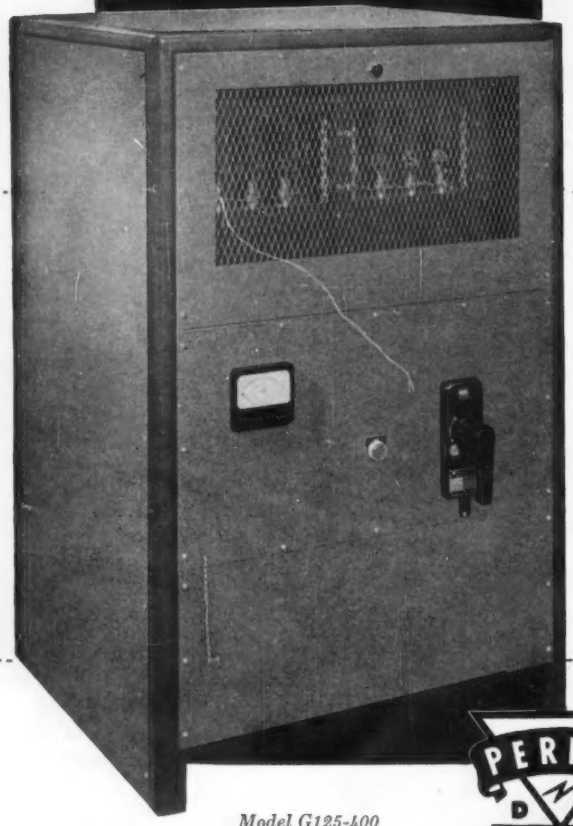
For more information circle 12 on reader service card.

**For DC Power Applications...**

# NEW PERKIN 50 KW Standard GERMANIUM RECTIFIER UNIT

FEATURES

- Can be **series or parallel connected** for higher voltage and amperage
- 94% Efficiency
- Low installation cost (no special mounting required)
- Excellent Power Factor
- No moving parts (except cooling fan)
- Less floor space
- No warm-up
- Delivery—stock or 8 weeks



*Model G125-400 50 KW Germanium Rectifier Unit*

Through the unique characteristics of germanium, the new Perkin Model G125-400 50 KW Germanium Power Unit offers extremely high efficiency and a low installation and operating cost.

**This unit is ideally suited for such applications as: Municipal DC to AC conversion programs, DC Motors and controls, magnetic devices, brakes, chucks, clutches, lifting magnets, in place of mercury-arc, ignitron or mechanical rectifiers, electro-chemical and other general industrial DC power applications.**

A key feature of this model is the fact that two or more units may be connected in series or parallel and operated at one time for higher voltage and amperage.

Perkin also manufactures other heavy duty rectifier units (selenium and germanium).

**Send your specifications to Perkin for prompt recommendations and quotations.**

SPECIFICATIONS:

| | |
|---|---|
| **A.C. INPUT:** | 230/460 V., 60 Cycle, 3 Phase |
| **D.C. OUTPUT:** | 115-125 Volts @ 400 Amperes<br>*Available also connected for 62.5 V. @ 800 Amperes* |
| **CONTROL:** | Air Circuit Breaker |
| **VOLTAGE REGULATION:** | 5% No Load to Full Load |
| **DUTY CYCLE:** | Continuous |
| **RIPPLE:** | 5% RMS |
| **EFFICIENCY:** | 94% |
| **POWER FACTOR:** | 95% |
| **COOLING:** | Forced Air Cooling |
| **METERS:** | Ammeter |
| **WEIGHT:** | 1200 Lbs. *Approx.* |
| **FINISH:** | Gray Wrinkle Baked Enamel |
| **CONSTRUCTION:** | Floor Standing Cabinet |
| **DIMENSIONS:** | 34" W x 30" D x 52" H |

PERKIN D C power supplies

**PERKIN**
**ENGINEERING CORPORATION**
345 KANSAS ST. • EL SEGUNDO, CALIF.
ORegon 8-7215 or EAstgate 2-1375




For more information circle 13 on reader service card.

LOW VOLTAGE SWITCHGEAR through 600 v a-c, 250 v d-c, 15,000 through 150,000 amp interrupting, 6000 amp continuous.



UNIT SUBSTATIONS—primary and secondary, indoor and outdoor construction—in all standard ratings, dry, askarel or oil transformers.



ISOLATED PHASE BUS through 138 kv and 10,000 amp.



METAL-CLAD SWITCHGEAR in ratings from 2400 v through 15 kv, 50 through 750 mva interrupting and 3000 amp continuous.



INDIVIDUAL BREAKERS, a-c and d-c, 15,000 through 150,000 amp interrupting, 6000 amp continuous.



NONSEGREGATED PHASE BUS through 15 kv and 6000 amp.

## Economical: an I-T-E Power Package

An I-T-E Power Package includes the complete power handling facilities for a new construction project, building addition, or expansion of electrical service—one unit or a complete system for every application from generation to end use. You save in sound planning, easier installation, coordinated delivery, and assured performance—a better investment in every way.

For more information, contact the I-T-E sales office nearest you or write I-T-E Circuit Breaker Company, 19th & Hamilton Sts., Philadelphia 30, Pa.

**I-T-E CIRCUIT BREAKER COMPANY**
**Switchgear Division**



For more information circle 14 on reader service card.

Original 120 TRIMPOT

BOURNS now offers an expanded line of

TRIMPOTS®

...7 stock models of sub-miniature potentiometers to serve many special needs—at no extra cost!

First there's the 120 Wirewound TRIMPOT, with features common to all other BOURNS TRIMPOTS. It's a 25-turn potentiometer, easily adjusted, and weighing only 0.1 oz. Rectangular in shape, it fits readily into miniature electronic circuits. You can mount it individually, or stack it compactly with standard screws. Mountings are interchangeable with those on all other TRIMPOTS.

The self-locking shaft holds stable settings under extreme environmental conditions. All parts are corrosion resistant. Every unit is inspected 100% for guaranteed specifications. Resistances: 10 to 20,000 ohms, with resolutions as low as 0.2%.

Now, to give designers greater latitude, BOURNS has developed and is manufacturing the following standard models—variations of the Model 120.

**120 TRIMPOT**
*—Carbon*
Infinite resolution is provided by the carbon element. Resistances are higher, ranging from 20,000 ohms to 1 megohm.

**130 TRIMPOT**
*—Solder Lug*
For wiring direct to the instrument, using soldering iron or dip soldering techniques. Usable range of 98%.

**132 TRIMR**
*—Variable Resistor*
High resistances—up to 50,000 ohms in a wirewound rheostat.

**209 TWINPOT**
*—Dual Potentiometer*
Two outputs electrically independent, and controlled simultaneously by one adjustment.

**160 TRIMPOT**
*—High Temperature*
Operates at 175°C. High power rating: 0.6 watt at 50°C.

**230 TRIMPOT**
*—Humidity-proof*
Completely sealed, unit meets MIL-E-5272A Specifications for humidity.

*Write for literature on the BOURNS TRIMPOT line.*

BOURNS LABORATORIES

General Offices: 6135 Magnolia Ave., Riverside, Calif.
Plants: Riverside, California—Ames, Iowa

▲ Circle 15 on the card.



# BIBLIOGRAPHY ON POWER CAPACITORS 1925-1950

This Bibliography (S-43) was prepared as an activity of the Capacitor Subcommittee of the AIEE Committee on Transmission and Distribution and is intended to present a consolidated reference to the principal significant literature in the field of capacitor applications to power circuits. Only basic and original material has been presented.

Contents of this new publication include:

(1) LIST OF PERIODICALS

(2) BIBLIOGRAPHY ON POWER CAPACITORS, catalogued into the following divisions:

Capacitor Economics

Capacitors *(their design, construction, operation, and maintenance)*

Capacitor Applications *(miscellaneous, and general, industrial, and utility power factor correction)*

(3) BOOKS AND RELATED BIBLIOGRAPHIES

(4) AUTHOR INDEX

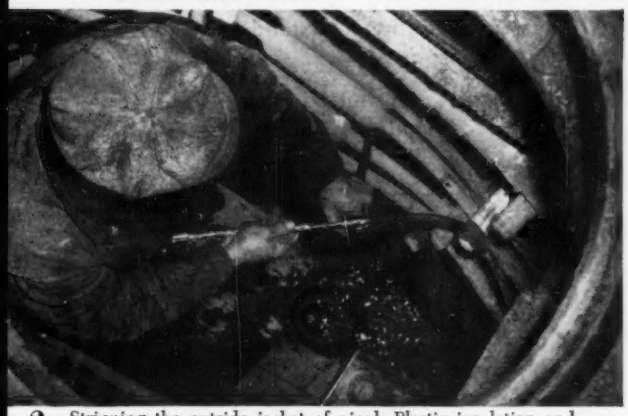
The price is $1.25 (no discounts possible). Copies may be obtained from:

Order Department
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street
New York 18, N. Y.

11-56

**1.** Reel containing 5,055 feet of polyethylene-insulated supervisory cable being unloaded.

**2.** Making pig-tail splices on the polyethylene-insulated conductors. Operation took about half hour for 16-pair cable.



**3.** Stripping the outside jacket of vinyl. Plastic insulation and jacketing are easy to strip for fast splicing.

**4.** Soaping the cable to aid in pulling. Average length was 1000 feet, pulled by hand.

## *Worcester, Mass.—*

# Major utility installs polyethylene-insulated supervisory cable

These pictures show some steps in making one of the largest installations of supervisory cable for speeding location of faults in tie lines. Installation was made by Worcester County Electric Co., subsidiary of New England Power Co. It connects two substations with each other and the central generating station.

The cable has 16 pairs of No. 19 gauge conductors, each insulated with moisture-resistant BAKELITE Brand Polyethylene, with an outer jacket of tough, abrasion resistant vinyl plastic. The cable operates relays at opposite ends of the tie lines so that lines can be cleared in case of trouble.

Crews worked twice as fast as with earlier cable because the plastic construction makes this cable lighter, smaller, and easier to splice. Greater lengths were pulled through—the average was 1000 ft.—and pulling was by hand. Only a quarter of the usual splices were needed, each taking about half an hour.

BAKELITE Brand Polyethylene is being used extensively on utility line wire, service drop, power cable, and coaxial cable. It satisfies REA requirements for plastic-covered telephone wire, meets applicable IPCEA specifications for service drop cable, ASA standards for weatherproof wire, ASTM D1238-52 Type II, dielectric materials, and IMSA specifications for fire alarm and signal control cable.

Cable shown is "Ankoseal" manufactured by **The Ansonia Wire & Cable Co.**, Ashton, R. I.

BAKELITE BRAND PLASTICS

**BAKELITE COMPANY,** *A Division of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N. Y.

*In Canada:* Bakelite Company, Division of Union Carbide Canada Limited, Belleville, Ontario

The term BAKELITE and the Trefoil Symbol are registered trade-marks of UCC

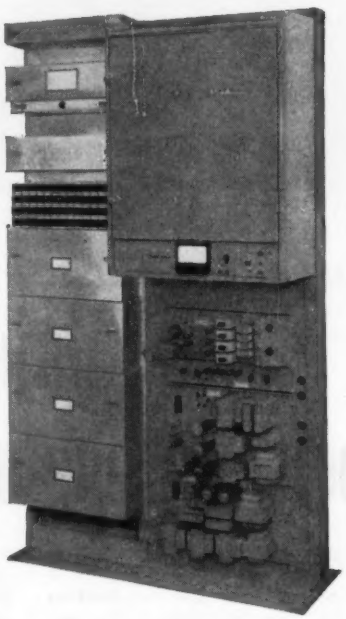
**For more information circle 16 on readers service card.** **Circle 17 ▶**

# NEW! PHILCO

HERE are new Microwave "Packages" by Philco, pioneer in the design and manufacture of microwave systems. Each new package incorporates advanced techniques in communications and control. All components have been selected for superior performance and greatest reliability. Outstanding features of Philco Microwave Packages can lower your installation and operating costs; write Philco now for complete information.

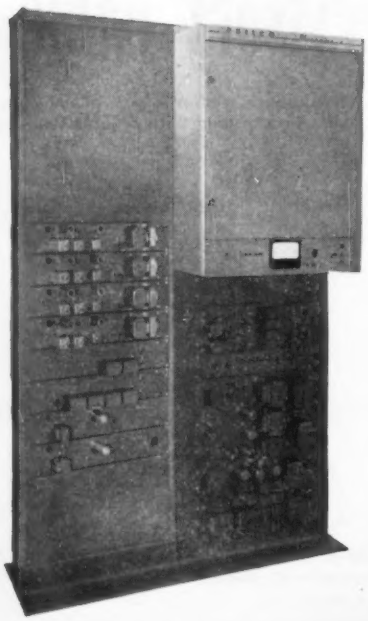
## PHILCO Series 500

Philco Series 500 Package is designed primarily for pipe line and railroad companies requiring maximum dependability consistent with highest commercial performance standards along extensive right-of-way routes.



### FEATURES

- Expandable to 24 or more channels (plus service channel)
- Extendable to 40 hops (1000 miles)
- Commercial quality circuits



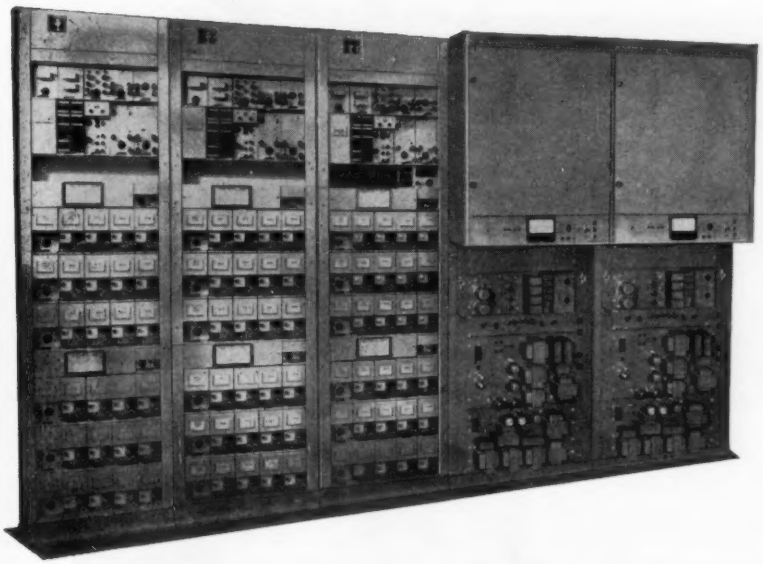
## PHILCO Series 120

Philco Series 120 Package is designed to provide low cost, reliable communications over moderate distances for turnpikes, police, and utilities.

### FEATURES

- Lowest cost per channel mile
- Expandable to 24 or more channels (plus service channel)
- Extendable to 10 hops
- Commercial quality circuits

# Microwave "Packages"



## PHILCO Series 90

Philco Series 90 Package is designed to provide the high performance and reliability required by common carriers and government agencies. Full 100% standby with completely automatic switching is included.

### FEATURES

- Utmost reliability
- Expandable to 60 channels
- Extendable to 5 or more hops

Philco maintains a staff of experienced engineers to conduct surveys, plan, and install complete systems to satisfy even the most complex communications requirements. These men have successfully completed thousands of system miles, including one of the longest microwave communications systems in the world.

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QUALITY
the World Over

## PHILCO CORPORATION

GOVERNMENT AND INDUSTRIAL DIVISION • PHILADELPHIA 44 PENNSYLVANIA

*In Canada: Philco Corporation of Canada, Limited, Don Mills, Ontario*

# SELECTED COMPOUNDS
## in felted asbestos walls
## + quality varnished cambric tapes
## add up to
# ROCKBESTOS A.V.C.
## (N.E.C. TYPE AVA) QUALITY

Pictured is the application of fluffy asbestos prior to the impregnating and compressing process.

Impregnated asbestos compressed and felted to a smooth homogeneous wall ensuring long cable life.

Compounds — specially selected compounds — which are used to impregnate asbestos walls, are one of the important reasons why you can count on Rockbestos A.V.C. for dependable, long lasting service.

For this impregnation, Rockbestos engineers not only set up rigid compound specifications but conduct a continuing testing program to insure that these standards are always met. Thus, the exactly right compound is applied to the asbestos wall at the correct temperature and at the correct pressure. *The Result . . . the seamless, felted Rockbestos wall.*

In Rockbestos A.V.C. impregnated felted asbestos walls seal varnished cambric tapes away from air and moisture. The tapes are made to Rockbestos specifications and are applied under controlled methods assuring uniform dielectric strength.

Rockbestos A.V.C. gives you long life and dependable service under every type of operating condition . . . in temperatures up to 230°F.

Complete construction and test specifications of Rockbestos A.V.C. are in the new booklet "Specification RSS-88". Write today for your copy.

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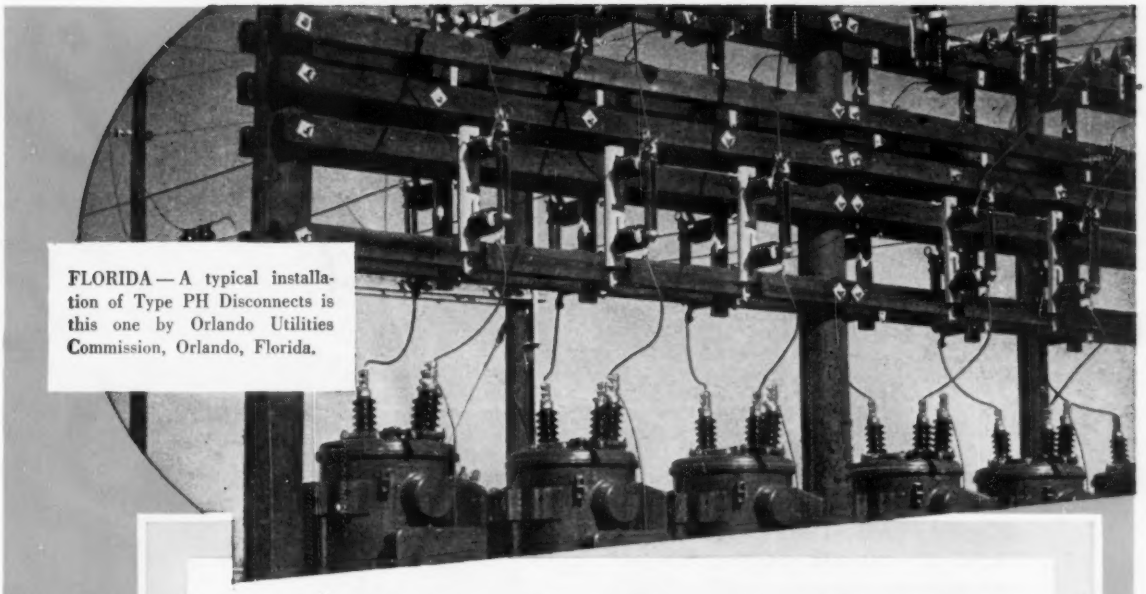
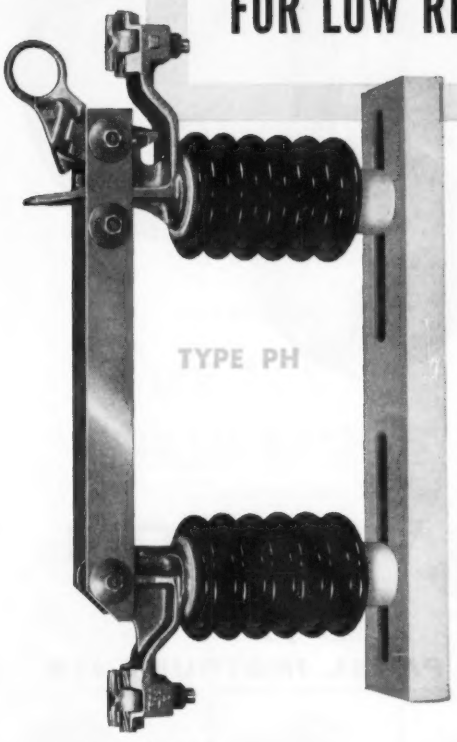
**For more information circle 18 on reader service card.**



FLORIDA — A typical installation of Type PH Disconnects is this one by Orlando Utilities Commission, Orlando, Florida.

# A LOW-COST, HIGH-QUALITY DISCONNECT FOR LOW REVENUE DISTRIBUTION LINES




## SOUTHERN STATES TYPE PH HAS MANY DESIGN EXTRAS

It is often difficult to justify expensive switches for isolating, by-passing, or disconnecting on low revenue distribution lines. Yet the mechanical features of such disconnects are highly desirable, as any operating man knows.

That is why Southern States designed its popular, low-priced Type PH Disconnect. Its cost is easily justified, and yet it has many design extras found on more expensive switching equipment. For instance:

- **High-pressure line contacts**
- **Integral terminals**
- **Rugged parallel blade construction**
- **Blade pry-out action**
- **Positive blade latching**

This single throw, single pole, hookstick-operated switch designed for wood crossarm mounting, is answering the requirements for many utilities throughout the nation. You will find it profitable too. For full details, write for Bulletin 54 PH.

**CHANNEL OR ROLLED FLANGE STEEL BASES ARE AVAILABLE.**

**SOUTHERN STATES EQUIPMENT CORP.**
HAMPTON, GEORGIA

IN CANADA: Dominion Cutout Co., Ltd., Toronto



For more information circle 19 on reader service card.

*absorb*

# SHOCK

*like a stack of cushions*

Components must be *more* than tough to stand up under the punishment to which ground support equipment is subjected. That's why WESTON Ruggedized instruments are favorites for applications when severe shock and vibration are encountered . . . as well as for mobile equipment requiring instruments that will continue functioning—*accurately*—through shock, vibration, moisture, or temperature extremes. AVAILABLE IN ALL REQUIRED SIZES, IN A-C, D-C, RF AND THERMO TYPES. For the complete story on Weston Ruggedized instruments, or on other instruments for panel, laboratory, production or servicing needs, consult your nearest Weston representative, or write Weston Electrical Instrument Corp., Newark 5, N. J.

**WESTON**

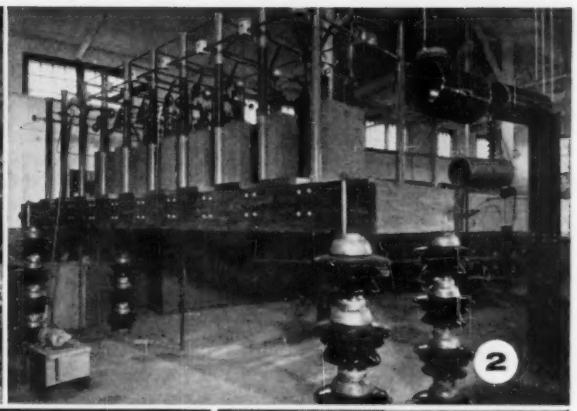
*Ruggedized*

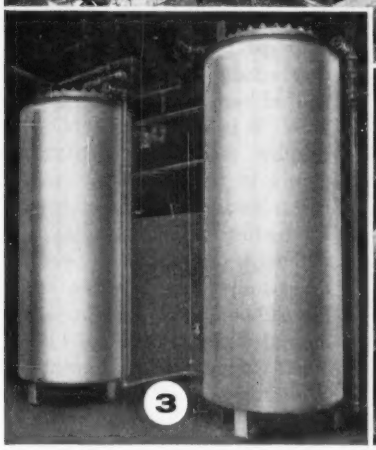
**PANEL INSTRUMENTS**

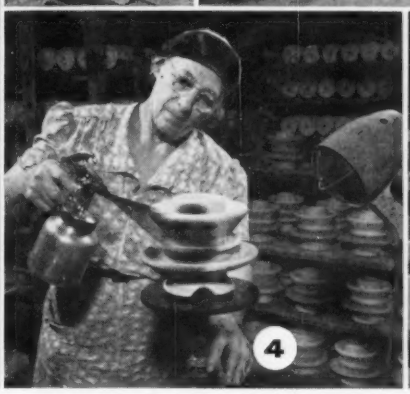
A DAYSTROM UNIT




For more information circle 20 on reader service card.



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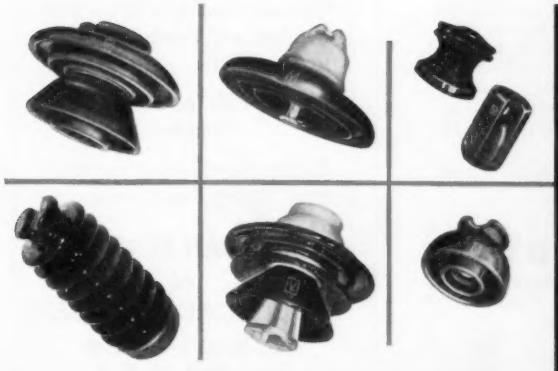
## VICTOR GIVES YOU BETTER INSULATORS

1. Demand for VICTOR Insulators has necessitated a continual plant expansion running into many millions of dollars. In the last seven years alone, our plant area has been increased 20% to provide greater space for manufacturing, storage and research!
2. This impulse generator in VICTOR'S electrical laboratory, enables our engineers to perform steep front wave tests as well as standard impulse tests.
3. All processing water used by VICTOR is demineralized. VICTOR was the *first* in the industry to install water demineralizing equipment. A patent on our process is now pending.
4. To certify insulator soundness, VICTOR uses black light. Unfired insulators are sprayed with fluorescent material, then subjected to a near ultra-violet light source.
5. This hydraulic testing machine in VICTOR'S specialty porcelain department gives open cutouts and similar insulators a routine calculated transverse load before electrical test.



"BETTER INSULATORS THROUGH RESEARCH"

• SPECIFY VICTOR Purified Porcelain Insulators!

VICTOR INSULATORS DIVISION
I-T-E CIRCUIT BREAKER CO.
VICTOR, N. Y.

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**. . . THE SUPER-CURRENT SLAYER**

When you want to kill giant Short-Circuits almost before they start — some form of Amp-trap can do it. Amp-trap will limit peak available short-circuit currents on low voltage circuits and prevent them from developing full magnetic or thermal destructive force. Ask about Amp-trap and its many capacities and arrangements. Find out about this amazing current limiter now. It is an entirely new form of protective device with current limiting action on short-circuit currents up to 100,000 Amperes R.M.S. or 200,000 Amperes (peak), at 600 Volts. Because Amp-trap *anticipates* destruction it protects your investment by eliminating the need for replacement. Write for Bulletin 514. There is no obligation.

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THE **CHASE-SHAWMUT** CO.
373 MERRIMAC STREET • NEWBURYPORT, MASSACHUSETTS

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▲ Circle 22 on the card.



## Bibliography on High-Pressure Electric Arcs

### (May 1954)

This Bibliography (S-62) has been prepared to aid those conducting research in the field of high pressure electric arcs. It is hoped the Bibliography will also stimulate others to become interested in this fundamental and highly fascinating field of research. Although the work has been done under the auspices of the Subcommittee on Fundamental Arc Research of the AIEE Committee on Electric Welding, the Bibliography should prove useful to all fields of high pressure arc research, whether the application be to arc welding, arc refining, or arc extinction. The Bibliography has been compiled from a number of sources, including many privately donated bibliographies as well as extensive searches through standard journals. Entries are arranged alphabetically according to author. They include, in addition to the author's name, the title of the article, the name of the publication, the volume, number, and date of the publication, and number of pages in the article.

Price: $1.50 (no discounts for members)

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An electrically-controlled pneumatic-hydraulic tool combining the convenience of a hand tool and the power of a bench press . . . Mounted on a portable cart which serves as a support . . . Power unit and tool may be detached for use in hard-to-reach locations . . . Operated either by foot pedal or thumb contact button . . . Adapted for use on A-MP Solistrand, Ampli-Bond and Aluminum terminals.

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**For more information circle 23 on reader service card.**

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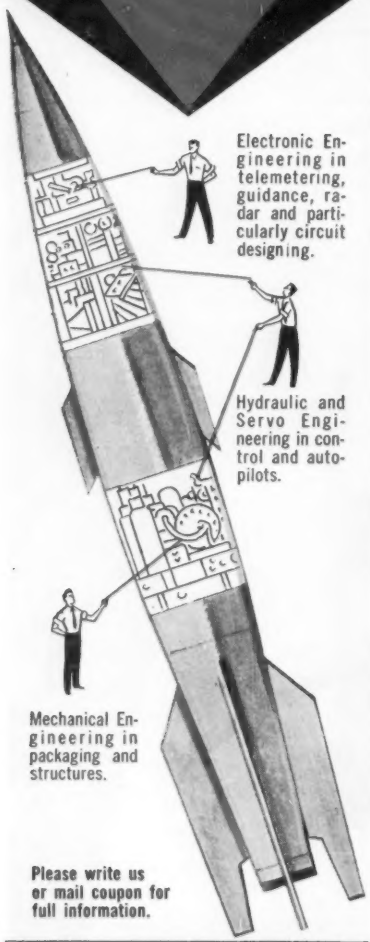

Electronic Engineering in telemetering, guidance, radar and particularly circuit designing.

Hydraulic and Servo Engineering in control and autopilots.

Mechanical Engineering in packaging and structures.

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I am a graduate engineer with____degree.
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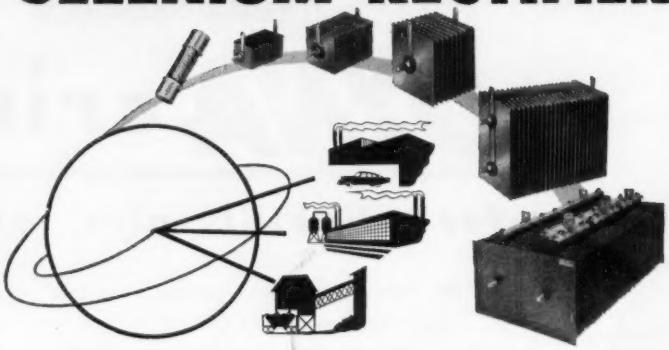
# SELENIUM RECTIFIERS



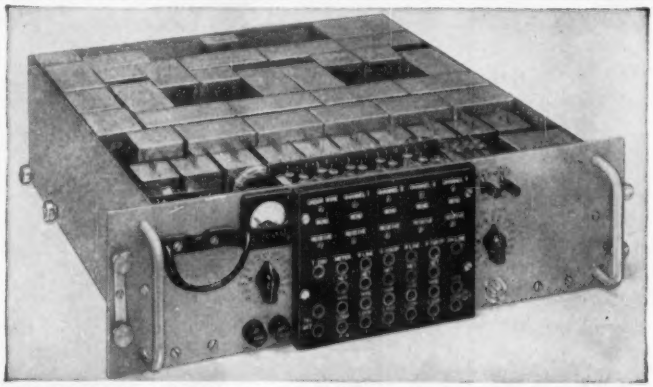
**Widest range of cell ratings in the industry**

A highly efficient and economical means of converting a-c to d-c power is obtained with SYNTRON quality controlled vapor processed SELENIUM RECTIFIERS. Constructed to withstand shock and vibration—treated against adverse climatic conditions—require no warm-up time—low forward voltage drop, more efficiency, and low ageing plus longer life. Trouble free, maintenance free operation. Widest range of cell ratings in the industry.

*Write for complete catalogue data—FREE*

**SYNTRON COMPANY**
440 Lexington Avenue Homer City, Penna.

▲ Circle 24 on the card. ▼ Circle 25.



**FOUR-CHANNEL CARRIER-TELEPHONE TERMINAL FOR RADIO LINKS**

This is a miniaturized unit of advanced design which provides four voice channels on a frequency-division basis above a voice-frequency order-wire channel. Each of these five channels is provided with a 4-wire 2-wire termination and a voice-frequency ringing circuit for d-c or 20-cycle signals. Adjustable attenuators are provided in the 4-wire side of all channels, and a built-in test oscillator and meter permit complete line-up, maintenance and trouble-shooting checks to be made. Channel levels are from −9 to 0 dbm and line levels from −30 to 0 dbm. Channel width is 300 to 3500 cycles within 1 db.

This unit is only 5¼″ high by 19″ wide by 14″ deep. It mounts on a standard rack and operates from 115 volts 50-60 cycles a.c.

**RADIO ENGINEERING PRODUCTS**
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# GENERAL CABLE'S HIGH QUALITY CONTROL CABLE with IMPROVED COLOR CODING

To preserve the superior physical characteristics inherent in black neoprene, General Cable applies a colored synthetic rubber base coating supplemented, where necessary, by spiral striping over the black neoprene jacket of individual conductors.

This new, carefully developed method of color coding the individual conductors of multiple conductor cable results in superior quality, brighter colors and an extra tough coating for permanence.

Station, Traffic, Elevator and Railway control cables are color coded in accordance with IPCEA Standard color sequence and to customer's specifications.

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420 Lexington Avenue,
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Offices and Distribution Centers
Coast-to-Coast.

*for quality and service . . .* specify **GENERAL CABLE**



For more information circle 26 on reader service card.

# New TEKTRONIX Cabinet Design

**Improved three-piece cabinet lets you make internal adjustments faster, easier. Five popular Tektronix Oscilloscopes ...Types 541, 545, 531, 535, and 532...are now manufactured in this new mechanical form.**

Periodic recalibration of your oscilloscope assures the high degree of measurement accuracy so important in research and development work. Your convenience in this infrequent but critical operation was the motivation behind the improved mechanical construction of these five laboratory oscilloscopes. Either side of the new cabinet can be lowered out of the way or quickly removed by merely releasing two quick-opening fasteners. No need to disconnect or move the instrument from its operating position. Internal adjustments and tube replacements are now really easy to make, enabling you to keep your oscilloscope at its peak of precision with a minimum of effort.

These five oscilloscopes, although improved in appearance and accessibility, are unchanged electrically. The basic oscilloscope specifications are such that one of the general-purpose plug-in vertical preamplifiers adapts the instruments to practically all ordinary applications. Six additional plug-in units are available for the more specialized applications frequently encountered in many research and development activities.

**TYPE 541 OSCILLOSCOPE** — dc to 30 mc with Fast-Rise Plug-In Unit. Calibrated sweep range from 0.02 μsec/cm to 5 sec/cm. 10-KV accelerating potential. 0.2-μsec signal delay, 4-cm linear vertical deflection, electronically regulated power supplies, square-wave amplitude calibrator. Price, without plug-in units, **$1145.**

**TYPE 545 OSCILLOSCOPE** — Same as Type 541 plus triggered and conventional sweep delay, rate pulse generator, and manual or electrical lock-out release for single triggered sweeps. Calibrated sweep-delay range, 1 μsec to 0.1 sec. Price, without plug-in units, **$1450.**

**TYPE 531 OSCILLOSCOPE** — dc to 1½ mc with Fast-Rise Plug-In Unit. 0.25-μsec signal delay, 6-cm linear vertical deflection. Other characteristics same as Type 541. Price, without plug-in units, **$995.**

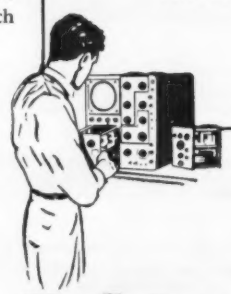
**TYPE 535 OSCILLOSCOPE** — Same as Type 531 plus sweep delay and other characteristics of the Type 545. Price, without plug-in units, **$1300.**

**TYPE 532 OSCILLOSCOPE** — dc to 5 mc vertical response. Calibrated sweep range from 0.2 μsec/cm to 5 sec/cm. 4-KV accelerating potential, 8-cm linear vertical deflection, electronically regulated power supplies, square-wave amplitude calibrator. Price, without plug-in units, **$825.**

## PLUG-IN PREAMPLIFIERS

| | |
|---|---|
| Type 53/54K Fast-Rise Unit | $125 |
| Type 53/54A Wide-Band Unit | 85 |
| Type 53/54B Wide-Band High-Gain Unit | 125 |
| Type 53/54C Dual-Trace Fast-Rise Unit | 275 |
| Type 53/54D High-Gain Differential Unit | 145 |
| Type 53/54E Low-Level Differential Unit | 165 |
| Type 53/54G Wide-Band Differential Unit | 175 |

Prices f.o.b. Portland, Oregon



Your Tektronix Field Engineer or Representative will be happy to furnish complete specifications and arrange a demonstration at your convenience.

**ENGINEERS**—interested in furthering the advancement of the oscilloscope? We have openings for men with creative design ability. Please write Richard Ropiequet, Vice President, Engineering.

# Tektronix, Inc.

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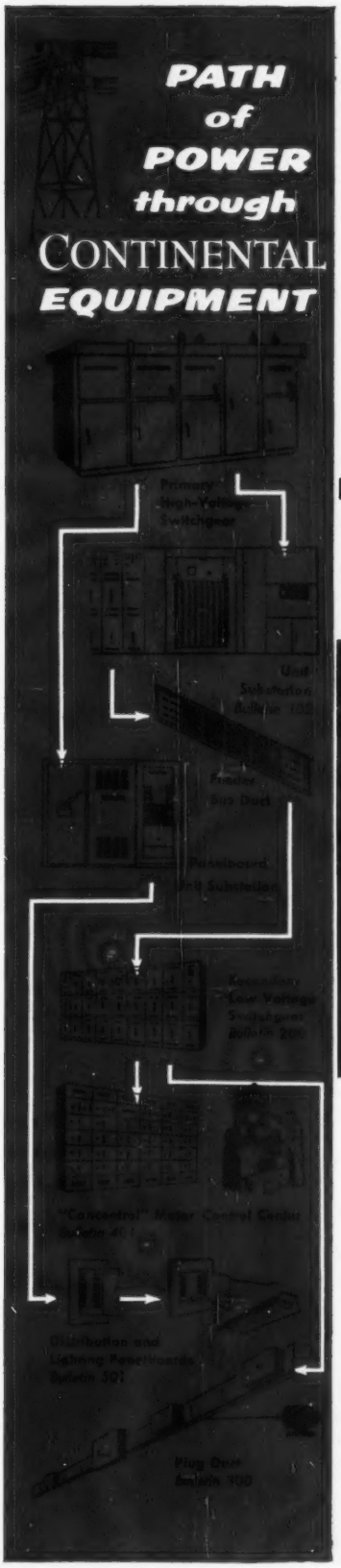
**Phone CYpress 2-2611 • TWX-PD 265 • Cable: TEKTRONIX**



**For more information circle 27 on reader service card.**

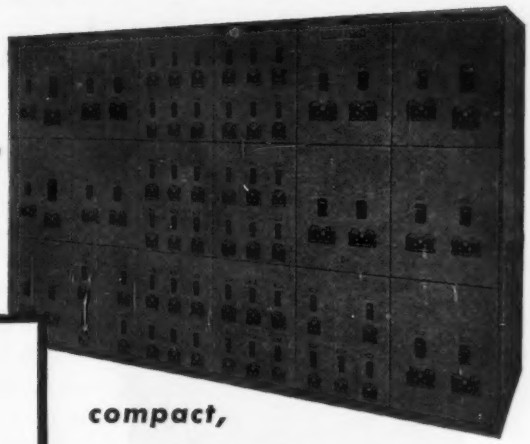


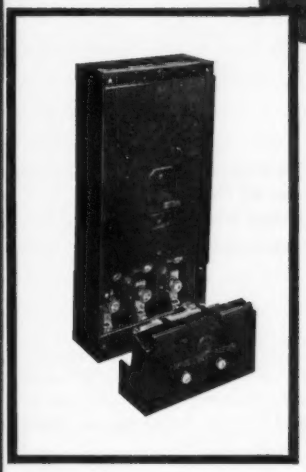

# CONTINENTAL Low Voltage

## DRAWOUT SWITCHGEAR

*featuring*

**NEW "CORDON" Current Limiting Circuit Breakers**





New draw-out "Amp-Trap", unusually compact current limiting fuse, makes combination breaker feasible.

*Compare for yourself. Write for detailed specifications today.*

***compact, low cost units with 100,000 amp interrupting rating***

This CONTINENTAL Low Voltage Switchgear offers attractive initial cost . . . plus a new protective device that solves high magnitude low-voltage short circuit current problem.

"Cordon" current limiting Circuit Breakers provide protection to 100,000 amp. rms interrupting rating, yet save you money. Add this important feature to the safety and economy of rigid, compact CONTINENTAL switchgear . . . the result is low cost, low maintenance equipment protecting you better than ever.

**DELIVERY: 6 WEEKS***

CONTINENTAL

**ELECTRIC EQUIPMENT CO.**

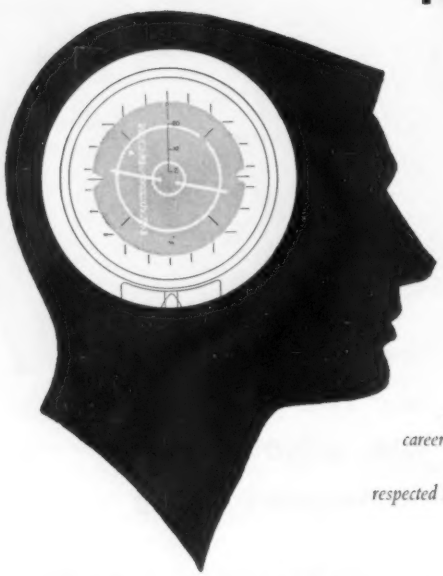
203 West 4th Street Cincinnati 2, Ohio

*Standardized units only, not requiring approval drawings. If approval drawings are required, add 2 weeks.



**For more information circle 28 on reader service card.**

# Systems Career: a laboratory for learning



*. . . an exciting and rewarding career awaits the E.E. or Physics graduate who joins this highly respected Engineering team.*

As a Field Engineer at Hughes, through training and assignment you will become familiar with the entire systems involved, including the most advanced electronic computers. With this knowledge you will be ideally situated to broaden your experience and learning for future application in either the military or commercial field.

The national respect which Hughes commands in the field of advanced electronics is in no small part due to the technical support provided by the Field Engineers. Other contributors to the success of the Field Service and Support Division are the Technical Manuals Engineer, Training School Engineers, Technical Liaison Engineers, and Field Modification Engineers.

This Hughes activity is a highly trained organization of expert engineers, giving support to the armed services and airframe manufacturers using the company's equipment. Locations are in Southern California, continental U.S., overseas. We invite you to join this team. For further information write us at the address below.

**HUGHES**

**Some extra advantages for Field Engineers include:**

Training at full salary for 3 months before assignment.

Generous moving and travel allowance between present location and Southern California (Culver City).

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*Scientific Staff Relations*
RESEARCH AND DEVELOPMENT LABORATORIES
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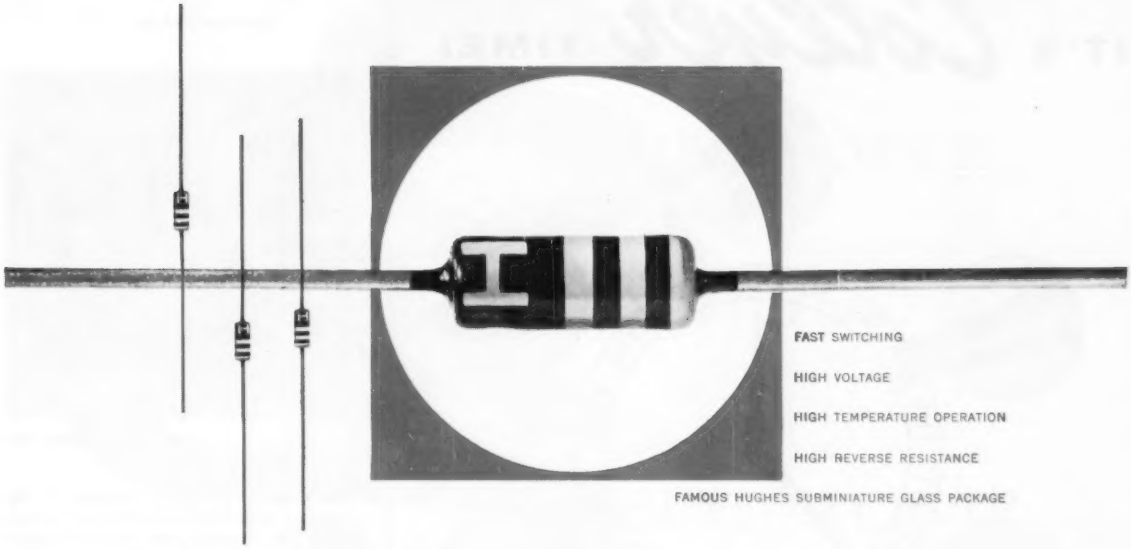

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HIGH VOLTAGE

HIGH TEMPERATURE OPERATION

HIGH REVERSE RESISTANCE

FAMOUS HUGHES SUBMINIATURE GLASS PACKAGE

# QUICK RECOVERY *Silicon Junction Diodes by Hughes*

DESIGN ENGINEERS—*Hughes Semiconductors now offers a new family of silicon junction diodes—especially designed to provide you with a device having significantly faster recovery characteristics than even germanium computer diodes and, in addition, capable of operating at high voltages and high temperatures. For the first time, this particular combination of characteristics—(high speed + high temperature + high voltage)—is available in a semiconductor.*

*Excellent high-frequency characteristics of the new diodes enable you to use them instead of vacuum or germanium diodes in such applications as:* FLIP-FLOP CIRCUITS . . . MODULATORS AND DEMODULATORS . . . DISCRIMINATOR CIRCUITS . . . CLAMPING AND GATING CIRCUITS . . . DETECTORS. *So, whenever you need a diode for pulse or computer circuitry to perform under conditions that are marginal for vacuum or germanium diodes, use the new* QUICK RECOVERY *Silicon Junction Diodes—by* HUGHES!

With a wide variety of germanium and silicon diode types available for computer and other fast switching applications, we are in a position impartially to recommend the best type for your particular requirements. Our field sales engineers near you are ready to assist you in making the best possible selection. For further details, or for specifications covering the new Quick Recovery Silicon Junction Diodes, write:

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A DIVISION OF THE HUGHES AIRCRAFT COMPANY

HUGHES PRODUCTS
SEMICONDUCTORS
*International Airport Station*
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RECOVERY
All types recover to 400K ohms in one μsec when switched from 30mA forward to 35V reverse. Special types with faster recovery are available if required.

WORKING INVERSE VOLTAGE
From 30 to 200 volts.

OPERATING TEMPERATURE RANGE
−55°C to +135°C.

ACTUAL SIZE, Diode Glass Body
Length: 0.265-inch, max.
Diameter: 0.105-inch, max.

TYPES NOW AVAILABLE
IN625, IN626, IN627, IN628, IN629.

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SEMICONDUCTORS

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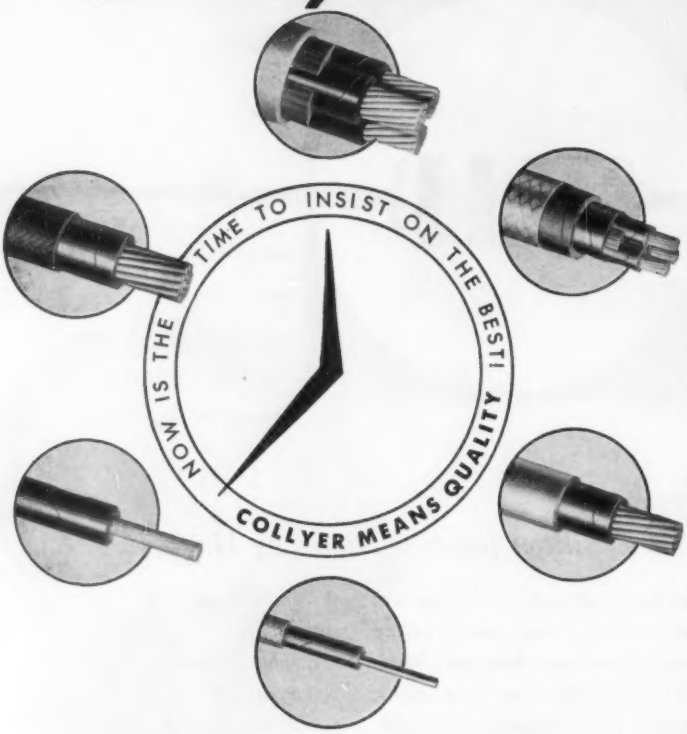
For more information circle 29 on reader service card.

IT'S *Collyer* TIME!

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Grounding Cables
Heavy Duty Portable Cables and Cords
High Voltage Cables
Lead Sheathed Cables
Line Wire
Machine Tool Wires
Mining Machine Cables
Motor and Generator Leads
Network Cables
Neutral Supported Service Cables
Non-Metallic Sheathed Cable (Cablex)
Pole and Bracket Cables
Resistol* Insulated and Sheathed Cables
Rubber Insulated Power Cables
Service Cables
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*Resistol is Collyer's Polyvinyl Thermoplastic Resin

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▲ Circle 30 on the card.


## Industrial Notes

(*Continued from page 14A*)

*Consolidated Electrodynamic Photo*

now available as optional features on the standard type *5-119* recording oscillograph made by Consolidated Electrodynamics Corporation, Pasadena, Calif. Through replacement or modification of all components subject to arcing, the new explosionproof design has been developed in accordance with safety requirements of military aircraft specifications for hazardous locations. The explosionproof model is for 400-cycle, 200-volt, 3-phase operation only. The new flash timing system permits absolute timing through an internal or external pulse source, and is designed to synchronize timing lines from 2 to 100 remotely located oscillographs. With the flash timing system, master units can control up to ten slaves. Up to 100 units can be slaved by adding a cathode follower to the system. Full details on both modifications are contained in CEC Bulletin *1536*, available from Consolidated Electrodynamics Corporation, 300 N. Sierra Madre Villa, Pasadena, Calif.

**Enamel Finish.** Phenolics, the dark-colored plastic materials familiarly used in telephone handsets, electric iron handles, and other appliance parts, can now be colored economically and permanently without the use of primers or multiple coats. Chemists at Rexton Finishes, Inc., Irvington, N. J., have developed an industrial finish, based on Bakelite epoxy resins, which adheres firmly to the glossiest phenolic surfaces. With the development of the new finish, these manufacturers can have color in a single coat and still retain the exceptional quality advantages and production economies of molding with phenolics. Bakelite epoxy resins used in the new enamel are well known for their adhesive properties. While the new finish was developed especially for use on phenolics, it works equally well on steel, tin, brass, copper, aluminum, zinc, glass, wood, and many plastics. Two steel bars spray coated with the new enamel can be banged together until the metal dents without chipping the coating. The new enamel also retains the excellent heat, corrosion, chemical and abrasion resistant characteristics

(*Continued on page 52A*)

# SILICON?

# GERMANIUM?

# SELENIUM?

**INTERNATIONAL'S Application Advisory Department can solve this problem for your application!**

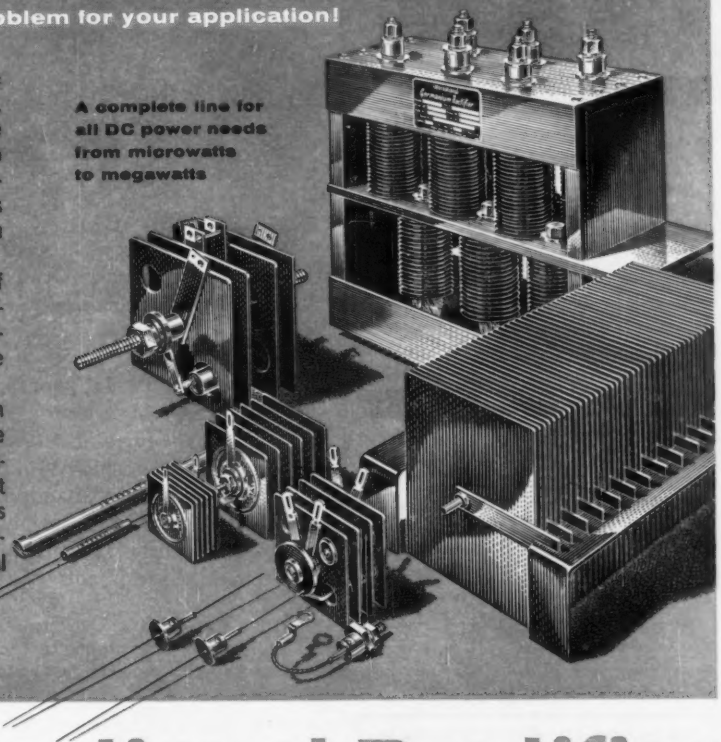
The distinct advantages of each of the semi-conductor materials, such as cost, efficiency, size, operating temperature range, and reliability, are well known to the design engineer. It is only after a careful analysis of the factors pertinent to his application that a concise determination of the prime factors can be established.

In a simple application, the selection of the **right** semi-conductor device is not difficult. It becomes a time-consuming problem with certain combinations of prime requirements.

If you have such a complex problem we invite you to avail yourselves of the services of our application advisory department, comprised of over 50 top-flight rectifier engineering specialists. This department will be more than glad to provide a prompt evaluation and a **practical** recommendation.

Just write, telephone or wire.

**A complete line for all DC power needs from microwatts to megawatts**



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# FREED

## MIL-T-27A POWER, FILAMENT, PULSE & AUDIO TRANSFORMERS

FOR IMMEDIATE DELIVERY FROM STOCK

### POWER TRANSFORMERS-STANDARD

All primaries 105/115/125 v., 60 c.p.s.

| Cat. No. | Hi Volt Sec. | ct | DC Volts | DC Amps | Filament #1 Volt | Filament #1 Amp. | Filament #2 Volt | Filament #2 Amp. | MIL Case Size |
|---|---|---|---|---|---|---|---|---|---|
| MGP1 | 400/200 | √ | 185 | .070 | 6.3/5 | 2 | 6.3 | 3 | HA |
| MGP2 | 650 | √ | 260 | .070 | 6.3/5 | 2 | 6.3 | 4 | JB |
| MGP3 | 650 | √ | 245 | .150 | 6.3 | 5 | 5.0 | 3 | KB |
| MGP4 | 800 | √ | 318 | .175 | 5.0 | 3 | 6.3 | 8 | LB |
| MGP5 | 900 | √ | 345 | .250 | 5.0 | 3 | 6.3 | 8 | MB |
| MGP6 | 700 | √ | 255 | .250 | | | | | KB |
| MGP7 | 1100 | √ | 419 | .250 | | | | | LB |
| MGP8 | 1600 | √ | 640 | .250 | | | | | NB |

### FILAMENT TRANSFORMERS-STANDARD

All primaries 105/115/125 v., 60 c.p.s.

| Cat. No. | Secondary Volt | Secondary Amp | Test VRMS | MIL Case |
|---|---|---|---|---|
| MGF1 | 2.5 | 3.0 | 2,500 | EB |
| MGF2 | 2.5 | 10.0 | 2,500 | GB |
| MGF3 | 5.0 | 3.0 | 2,500 | FB |
| MGF4 | 5.0 | 10.0 | 2,500 | HB |
| MGF5 | 6.3 | 2.0 | 2,500 | FB |
| MGF6 | 6.3 | 5.0 | 2,500 | GB |
| MGF7 | 6.3 | 10.0 | 2,500 | JB |
| MGF8 | 6.3 | 20.0 | 2,500 | KB |
| MGF9 | 2.5 | 10.0 | 10,000 | JB |
| MGF10 | 5.0 | 10.0 | 10,000 | KB |

### PULSE TRANSFORMERS

| Cat. No. | Block'g. Osc. | Int. Coup'g | Low. Pow. Out. | Pulse Voltage Kilovo.ts | Pulse Duration Microseconds | Duty Rate | No. of Wdgs. | Test Volt. KVRMS | Char. Imp. Ohms |
|---|---|---|---|---|---|---|---|---|---|
| MPT1 | √ | √ | | 0.25/0.25/0.25 | 0.2-1.0 | .004 | 3 | 0.7 | 250 |
| MPT2 | √ | √ | | 0.25/0.25 | 0.2-1.0 | .004 | 2 | 0.7 | 250 |
| MPT3 | √ | √ | | 0.5/0.5/0.5 | 0.2-1.5 | .002 | 3 | 1.0 | 250 |
| MPT4 | √ | √ | | 0.5/0.5 | 0.2-1.5 | .002 | 2 | 1.0 | 250 |
| MPT5 | √ | √ | | 0.5/0.5/0.5 | 0.5-2.0 | .002 | 3 | 1.0 | 500 |
| MPT6 | √ | √ | | 0.5/0.5 | 0.5-2.0 | .002 | 2 | 1.0 | 500 |
| MPT7 | √ | √ | √ | 0.7/0.7/0.7 | 0.5-1.5 | .002 | 3 | 1.5 | 200 |
| MPT8 | √ | √ | √ | 0.7/0.7 | 0.5-1.5 | .002 | 2 | 1.5 | 200 |
| MPT9 | √ | √ | √ | 1.0/1.0/1.0 | 0.7-3.5 | .002 | 3 | 2.0 | 200 |
| MPT10 | √ | √ | √ | 1.0/1.0 | 0.7-3.5 | .002 | 2 | 2.0 | 200 |
| MPT11 | √ | √ | √ | 1.0/1.0/1.0 | 1.0-5.0 | .002 | 3 | 2.0 | 500 |
| MPT12 | √ | √ | √ | 0.15/0.15/0.3/0.3 | 0.2-1.0 | .004 | 4 | 0.7 | 700 |

### AUDIO TRANSFORMERS

Frequ. resp. 300 to 10000 cps ± 2 DB. All Case Sizes AJ

| Catalog No. | Application | Impedance Prim. Ohms | Impedance Ct. | Impedance Sec. Ohms | DC Current Ct. | DC Current Prim. Sides MA Max. Unbal. MA | DC Current Sec. MA | Max. Level DBM |
|---|---|---|---|---|---|---|---|---|
| MGA1 | Single or P.P. Plates — to Single or P.P. Grids | 10K | √ | 90K Split | √ | 10 | 10 | +15 |
| MGA2 | Line to Voice Coil | 600 Split | | 4, 8, 16 | | 0 | 0 | +33 |
| MGA3 | Line to Single or P.P. Grids | 600 Split | | 135K | √ | 0 | 0 | +15 |
| MGA4 | Line to Line | 600 Split | | 600 Split | | 0 | 0 | +15 |
| MGA5 | Single Plate to Line | 7.6K 4.8T | | 600 Split | | 40 | 40 | +33 |
| MGA6 | Single Plate to Voice Coil | 7.0K 4.8T | | 4, 8, 16 | | 40 | 40 | +33 |
| MGA7 | Single or P.P. Plates to Line | 15K | √ | 600 Split | | 10 | 10 | +33 |
| MGA8 | P.P. Plates to Line | 24K | √ | 600 Split | | 10 | 1 | +30 |
| MGA9 | P.P. Plates to Line | 60K | √ | 600 Split | | 10 | 1 | +27 |

Send for further information on these units, or special designs. Also ask for complete laboratory test instrument catalog.

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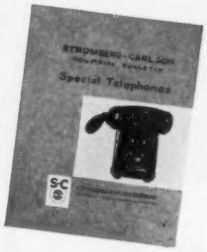
Shown above are just a handful, developed for somebody's special project.

*Suspended-type* 'phones, great space-savers; used either in dial or manual service.

*Remote-control* instruments, such as we make to work with dictating machines. "*Press-to-talk*," "*Press-to-receive*" and "*Press-to-control*" handsets, very popular in two-way radio applications. "*1574*" telephones, with a special key for transferring calls (or other functions) from one line to another.




NEW CATALOGUE, with complete description of all special-project instruments, sent you on request. Or for a specific problem, just write

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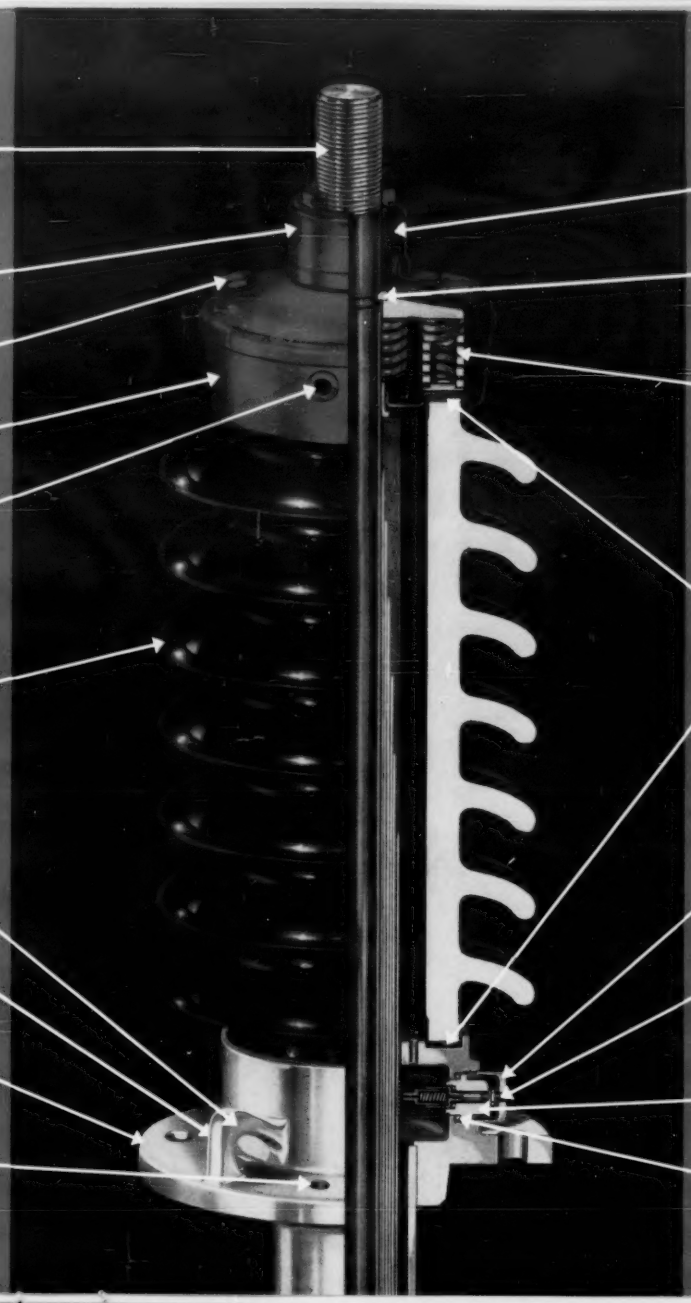
Circle 34 ▶

*Announcing...*

# Lapp POC* BUSHINGS

**ASA STANDARD**

***THE PAPER-OIL CONDENSER TYPE BUSHING THAT BRINGS THE OPERATING SECURITY OF TOTALLY-ENCLOSED MOISTURE-PROOF DESIGN FOR RATINGS 15 kv TO 69 kv**



Copper stud or draw-lead terminal, silver plated contact surfaces

Copper cover to protect bellows, painted red

Filler plugs, O-ring sealed

Drawn copper oil reservoir, painted red

Tapped hole for arcing horn

Lapp Fog Type corrugations, for most effective leakage distance, Vacuum Process chocolate brown glazed porcelain, with ground gasket surfaces

Two lifting eyes 180° apart

Aluminum nameplate attached with stainless steel screws

Heat-treated cast aluminum alloy flange

Threaded jacking screw holes, one in alignment for lower arcing horn

Solder-sealed phosphor bronze bellows unit to insure sealing with conductor movement

Stainless steel split locking ring

Multiple coil springs compressed to provide controlled permanent gasket loading

Confined Buna N-cork gaskets

Aluminum grounding cap

Power factor (grounding) tap, connected to copper band on outer foil layer of condenser core

Vacuum process glazed porcelain bushing, ground gasket surfaces

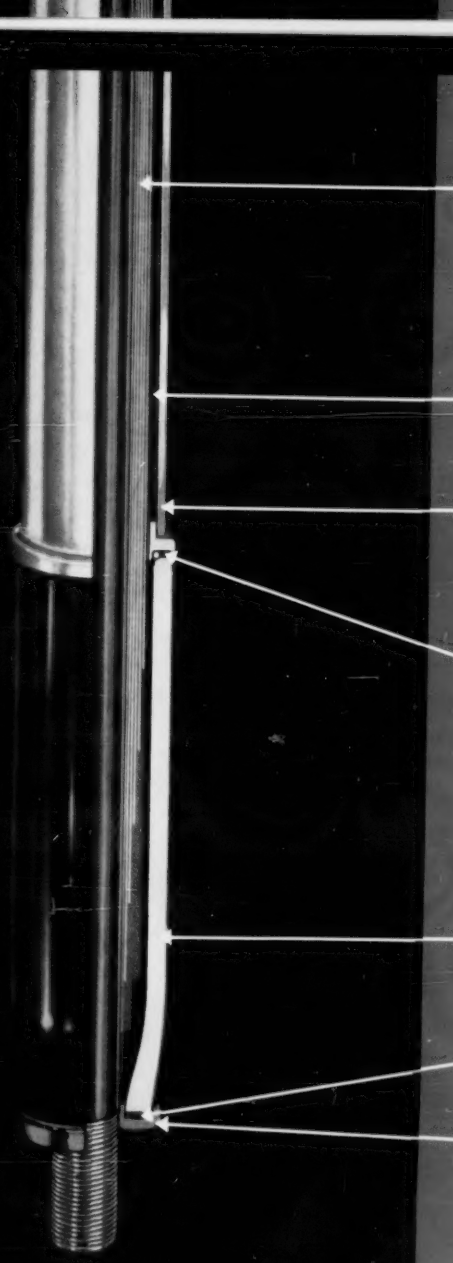
Buna N O-rings

# Lapp

# POC* BUSHING

***PAPER-OIL CONDENSER TYPE WITH TOTALLY ENCLOSED CORE**

**ASA STANDARD**



Condenser core, composed of oil-impregnated high dielectric paper, aluminum foil layers, wrapped on solid copper conductor for fixed stud, on copper tubing for draw-lead bushing

Oil space entire length of bushing

Heat-treated drawn aluminum alloy ground sleeve, welded to end castings

Combination gasket—hard Buna N-asbestos gaskets for mechanical loading, Buna N O-ring in precision ground recess for sealing under cantilever loading

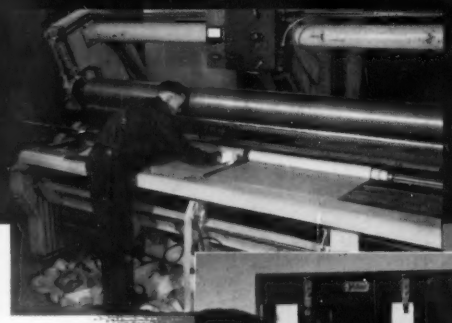
Porcelain ground to close tolerances to cooperate with metal parts for mechanical strength and resistance to impact under breaker duty

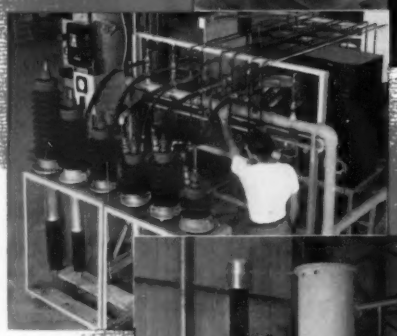
Confined Buna N-cork gaskets

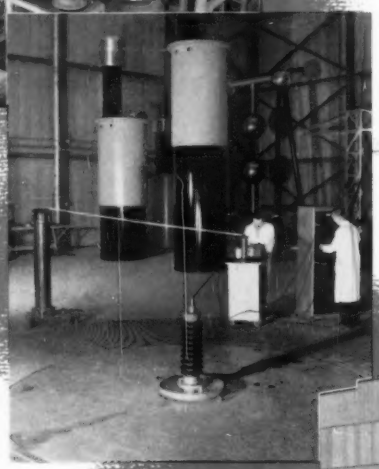
Forged copper cap, threaded and sweated to stud

# Lapp POC BUSHINGS

## provide the operating security of totally-enclosed moisture-proof design for ratings 15 kv to 69 kv







Paper-oil is the insulation used for bushings, cables and potheads of the highest voltages and where the maximum in reliability and trouble-free performance is essential. To provide the same order of operating security to equipment used at 15 kv to 69 kv, Lapp has adopted this design of construction for its new series of POC Bushings (ASA-NEMA standard).

**CONDENSER-TYPE CORE, SURROUNDED BY OIL**—The core is a condenser . . . multiple concentric layers of aluminum foil and kraft paper . . . which distributes voltage stress evenly throughout the insulation, to provide maximum insulation in smallest diameter. Impregnated with oil, the core is also entirely surrounded by oil, contained in a full-length porcelain-metal housing.

**SPRING-LOADED COMPRESSION SEALING**—Porcelain housings are Lapp Vacuum-process electrical porcelain. This inorganic material is non-tracking, will not deteriorate under leakage current. Leak-proof, moisture-proof sealing is accomplished by end-to-end spring-loading of compression gaskets.

**COMPLETE RANGE OF RATINGS AND SIZES**—In five voltage ratings, 15 kv through 69 kv, Lapp POC Bushings are rated at 1200 amps (with solid copper through-stud) and 400 amps (with draw-lead conductor). Six shank lengths in each voltage class provide for practically all new equipment and replacement needs.

At all rated voltages, Lapp POC Bushings are radio- and television-interference-free. They have a significantly low power factor, essentially unchanging under temperature or voltage variation.

***The new Lapp bushing building. High-voltage Laboratory (at left) contains equipment for 60-cycle testing to 1,050,000 volts, impulse testing to 2,250,000 volts, high-current testing to 10,000 amps. The section of the building at the right is devoted to core-winding, processing and assembly of oil-filled bushings.***

**Lapp**

**WRITE** for Bulletin 508 . . . complete description, specifications and characteristics of Lapp POC Bushings.
Lapp Insulator Co., Inc., LeRoy, N. Y.

*Another* **TRIANGLE** *multiple product Job*

# HOUSTON

*Everything's BIG in Texas—*
*and now Houston has added another BIG*

**$17,000,000 Building of Bank of the Southwest Opens Its Doors**

## 2,103,500′ of TRIANGLE WIRE AND CABLE
## 322,580′ of TRIANGLE CONDUIT

Bank of the Southwest. Its lobby, 63,000 square feet, is the largest in America. This ultra-modern building covers an acre and a half and rises 24 stories. The entire building is air conditioned by the largest electronically controlled system in the country.

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ENGINEER: H. E. Bovay (mechanical and electrical)
GENERAL CONTRACTOR: W. S. Bellows
ELECTRICAL CONTRACTOR: Fisk Electric Co.

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And every foot of Triangle material is top-quality because Triangle's manufacturing plants are equipped with the most modern production machinery and laboratory facilities available . . . operated by men who know their jobs.

*That's why those who know, specify* **TRIANGLE**
**IT MUST BE RIGHT**

## Let's take a Quick Look at TRIANGLE

Up to date research

Large stocks in redistribution centers

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Ever expanding plants

The Triangle Trademark is your guarantee of quality

*It Must Be Right*
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# TRIANGLE
## *Conduit and Cable Co., Inc.*
NEW BRUNSWICK, NEW JERSEY


For more information circle 35 on reader service card.

# Keeping production on the move with Westinghouse pushbuttons

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From Westinghouse you can get precisely the right operator, enclosure, whatever you need—when you need it. Complete lines of standard-duty, heavy-duty, and Oil-Tite* pushbuttons are stock items with Westinghouse.

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*Trade-Mark

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*WHERE **BIG** THINGS ARE HAPPENING FOR **YOU!***



For more information circle 36 on reader service card.

# Overhead Cables for Distribution

CURRENT TRENDS

No. 6 in a series of articles

Up until the last decade practically all overhead distribution involved some form of open-wire construction. Probably the most advantageous factor justifying this procedure has been economy plus an acceptable experience record. Like everything else, times are changing so that it is no longer axiomatic that open-wire circuits must continue to be used for overhead power distribution. Therefore, a brief story behind some of the modern cable designs for these applications may be of interest.

The need for cable is unquestioned. Overcrowded poles, severe tree conditions, storms, public relations, regulation problems and appearance are some of the contributing reasons for this need. The cable industry in recognition of this need has developed suitable cable products for almost every overhead distribution job and the Rome Cable Corporation has played a most active role in this progressive development. Cable costs have been so reduced by careful design and use of new materials that installed economies now closely approach open-wire construction in many instances. Today's distribution engineer would be remiss if he did not at least consider an appropriate type of cable for his new or replacement overhead distribution circuits. Rome Cable is prepared to supply all of these products and associated engineering services.

### Primaries

There is a definite trend towards aerial cable in the 5 kv to 15 kv range but it is difficult to conclude whether this trend is more in factory-assembled or the field-assembled variety, since there are merits for each.

In the 5 kv range the cost of cable compared to open-wire construction may not be too attractive when evaluated on the installed cost per mile of line, averaging approximately twice as much. In the 15 kv range this picture improves somewhat. However, if this comparison is based upon final installed cost per KVA this differential between cable and open wire is considerably narrowed. Naturally, there must be other determining reasons for using cable, such as improved appearance, resistance to storms, less tree trimming, better voltage regulation and greater reliability.

Preference for cable design in the 5 kv rating utilizes ozone-resistant rubber insulation (such as Rome Cable RoZone) with a suitable nonmetallic sheath (such as Rome Cable RoPrene or RoSeal) . . . unshielded and relatively easy to hot tap, particularly when the cable incorporates the "reverse-lay" feature. Economic preference for cable designs for the higher primary voltages, utilizes the same grade of insulation on each conductor covered with a bronze tape which serves as a combined shield and armor but makes "hot tapping" difficult and hazardous. These and other cables may be supplied with insulated copper or aluminum power conductors all properly bound to the correct Copperweld messenger as described in the new IPCEA-NEMA specifications for aerial cable or an equivalent type. Installation procedures for factory-assembled or field-spun cables are described in the technical literature as well as manufacturers' catalogs.

### Secondaries

Until quite recently there has been relatively little activity or interest in using cable for overhead secondaries but several utilities have been investigating and experimenting with either field- or factory-assembled cables for this application. Joint pole construction, elimination of crossarms, reduction of hardware, ease of installation, improved appearance, storm resistance, improved regulation and less tree trimming are some of the features to be realized, provided final installed cost is not prohibitive.

It is here that aluminum, at least for the phase conductors, seems to offer definite economic and technical advantages since the lighter weight is a most useful feature for line construction. With the advent of the now popular Triplex construction for service drops the idea of a similar factory-assembled cable for secondaries has certain merits. For single-phase secondaries, this cable generally consists of two insulated aluminum conductors (usually #1/0 or #2/0 AWG aluminum) spiralled around a suitable neutral messenger.

When this cable is used on conventional 150-foot pole spacings the service taps can be made at or near each pole with special fixtures now available. However, it is obvious that greater savings are possible with increased pole spacings and "flying" midspan service taps made where possible or convenient. Prefabricated devices to accomplish these taps have been developed. Thus, the combination of Triplex secondaries and services offer a new and advantageous construction idea at modest cost.

When secondary sizes larger than #2/0 AWG are required, either spinning or a cable construction similar to primary aerial cable is suggested.

### Services

The use of open-wire service drops is rapidly disappearing particularly in new construction and housing developments. Service drop cable, Type SD, utilizing concentric neutral has been too costly to merit universal acceptance unless some special feature such as reduced theft possibility was desired. Nine years ago the Rome Cable Corporation introduced the now popular neutral or self-supported Triplex type of service drop cable. This design received almost instant acceptance and has proven highly satisfactory. The power conductors, insulated with polyethylene or Neoprene, are spiralled around a neutral messenger in accordance with IPCEA recommendations.

Aluminum unquestionably offers economic and technical advantages for the power conductors and has become the general choice of metal for this particular application. A popular neutral messenger has been a reduced size ACSR but the idea of hard-drawn copper has been gaining favor, particularly where there is planning towards Triplex secondaries with Copperweld messengers in order to provide copper-to-copper contacts on the exposed neutrals. Consideration of this "combination" design is suggested.

For further information on Triplex services or secondaries we suggest you obtain Rome Cable Bulletins RS-5 and MST-1.

### Tree Wire

This discussion would not be complete without some reference to so-called Tree Wire installed on insulators for overhead construction. For primaries and unusually important secondary circuits this product would cost considerably less than insulated cable and somewhat more than weatherproof wire. Where extensive tree trimming is a problem or too costly the use of the newer low-cost special thermoplastic Tree Wire designs might be considered. Here, again, Rome Cable is ready with the information and the product.

**ROME CABLE CORPORATION, Rome, New York**



For more information circle 37 on reader service card.

*Now . . . a complete work station in only 32 square feet*

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- All metal construction with baked-on finish. No warping.
- Velvoleum covered drafting platform adjustable 0 to 85°.
- Height of entire unit adjustable from 30" to 39" at 1" intervals.
- Large center drawer. Locking instrument tray.
- Shelf and storage drawer arrangements to suit individual needs.
- Large sliding reference shelf for extra convenience.
- Designed for space-saving row installation.
- Accommodates parallel straight edge, drafting machine, lamp.
- Exclusive Flexi-Belt and Roto-Positioner delivers the work to the man.

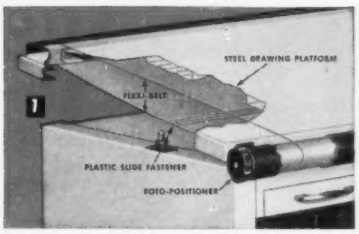
# Save valuable floor space with the new GF Draft-a-Matic®

When you install Draft-a-Matic you can conveniently accommodate one-third more draftsmen than with conventional desks and equipment.

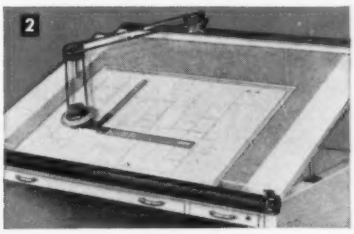
The draftsman needs only to make a half turn in his comfortable, adjustable office chair and there at his finger-tips are shelves for reference material, storage or file drawers and a sliding, Velvoleum covered work shelf. Drawer and shelf arrangement is flexible and can be tailored to individual needs or preference.

Draft-a-Matic not only solves the space problem—it boosts efficiency because the draftsman can perform his entire job while comfortably seated.

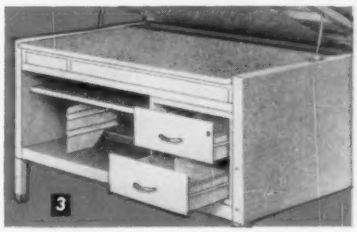
To learn the many ways Draft-a-Matic can help reduce your engineering costs, see it now at your local GF showroom, listed in the Yellow Pages. Or write for free 8-page Draft-a-Matic booklet. The General Fireproofing Company, Department L-60, Youngstown 1, Ohio.




1. *Drawing is affixed to endless vinyl plastic belt. By merely turning Roto-Positioner wheel, draftsman moves drawing into working range while remaining comfortably seated.*




2. *Draft-a-Matic will accommodate drafting machine, parallel straight edge, lamps and similar accessories. Drawing platform is covered with Mist Green Velvoleum.*




3. *Draftsman is surrounded by storage space so arranged as to serve best his individual requirements. This generally eliminates the need for additional files and book shelves.*

MODE-MAKER DESKS • GOODFORM ALUMINUM CHAIRS
SUPER-FILER MECHANIZED FILING EQUIPMENT • GF ADJUSTABLE STEEL SHELVING

**GF** metal business furniture is a **GOOD** investment

GF
**GENERAL FIREPROOFING**
*Foremost in Metal Business Furniture*



**For more information circle 38 on reader service card.**

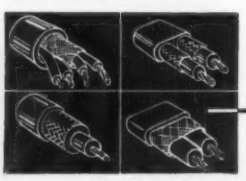
# *Don't Gamble With Cable Performance*

## ···*Depend on* PHALO!

"Almost" is never enough when it comes to cable performances. You must be 100% certain the cable you select is custom-made to do the job your power engineering plans call for. You must know you can depend on cable performance in every respect. Many of America's major users of cables have found they can depend on Phalo to produce *exactly* the cable needed.

Send Phalo a copy of your cable "specs". You'll discover a new kind of cable dependability.

*Ask For The Complete Phalo Catalog*



PHALO
PLASTICS CORPORATION
*The Custom Cable House*
25-E FOSTER STREET
WORCESTER, MASSACHUSETTS
Insulated Wires, Cables – Cord Set Assemblies

▲ Circle 39 on the card.

**Natural...Synthetic...Silicones**

# RUBBER

## SPECIALIZED PARTS BY EBERHARD FABER

The Rubber Division of Eberhard Faber develops and produces the quality parts you require from Natural Rubber, GRS, BUNA-N, Neoprene, Silicone. Rubber bonding of all types—specialty items molded, extruded or hand-built to your precise specifications.

Write for blueprint and specification study, field inspection, and cost analysis. Address inquiries to: DR. E. A. LOY, RUBBER DIVISION, DEPT. **EE-11**, EBERHARD FABER CO., 47 COLDEN STREET, NEWARK, NEW JERSEY.

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RUBBER FOR INDUSTRY FOR 50 YEARS

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**Qualified Engineers!**

**Engineering Societies Personnel Service**

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Employer pays fee in many cases

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See Personnel Section of this magazine for partial listing of jobs

**Register Today**

where **POWER** is **VITAL**

# ASCO AUTOMATIC TRANSFER SWITCHES help assure round-the-clock communications for Bell Telephone System

Each day millions of voices and scores of television and radio programs are flashed through some 50,000 miles of Bell System radio relay channels. Transmission through this vital chain of communications must be constant to meet the needs of a growing and busy America. That's why the Bell System has engineered complete safety and emergency features into many of its unmanned and often isolated radio relay stations.

Typical of these safety precautions are ASCO Transfer Switches which in case of failure of local power supply *automatically* transfer the load to an emergency power source.

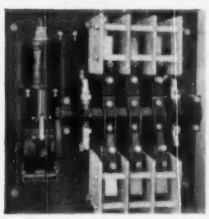
**Dependable Control by ASCO**

Where power and dependability are vital, ASCO switches give these signal design advantages: • **continuous duty rating** in either normal or emergency position • **capacity** to withstand inrush currents 20 times full load rating • **mechanical locking,** providing high contact pressure • **single coil design** • **built in time delay,** so that equipment ignores harmless momentary outages • **full phase protection,** and other design features.

For these reasons, many engineers today specify ASCO – the one source for a full line of dependable automatic transfer switches. *Write for Publication 596 describing how to select an adequate automatic transfer switch.*

## Dependable Emergency Power

Here is the ASCO Transfer Switch installed at Bell's Plainview, L. I., radio relay station.



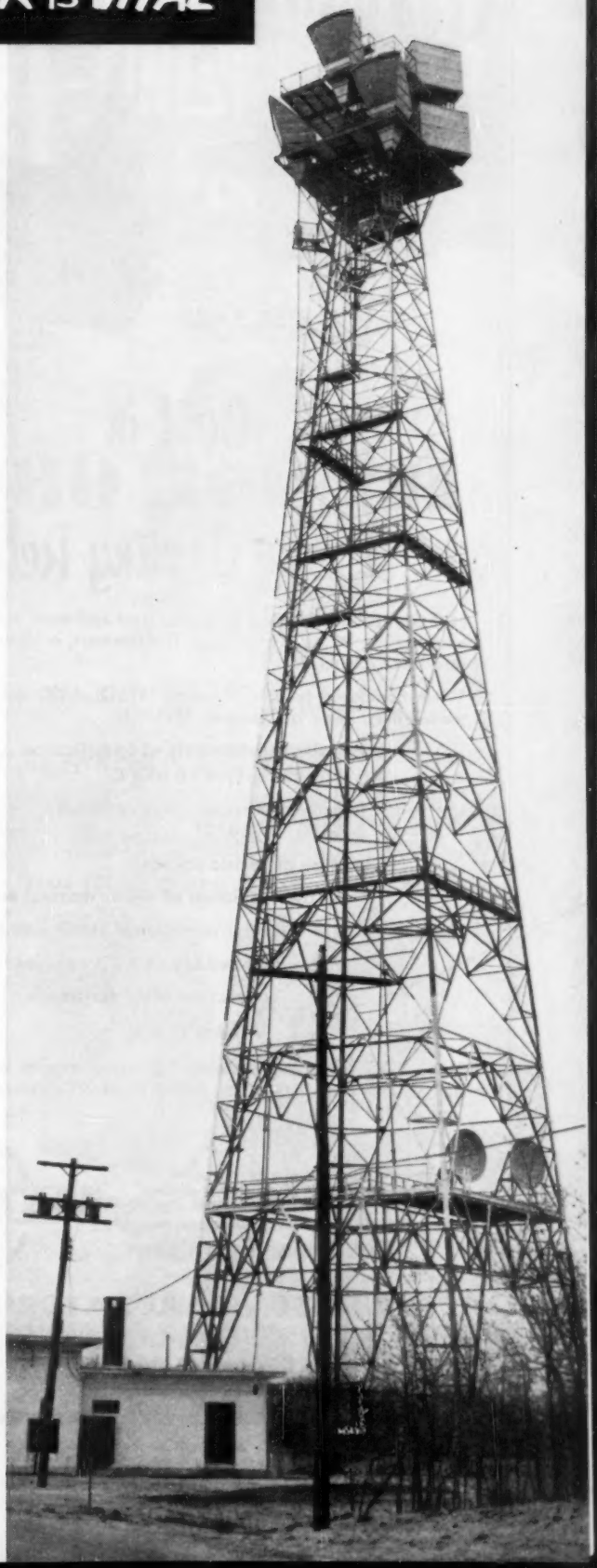
ASCO Automatic Transfer Switch – Bulletin 905. When normal power fails, this Switch transfers the load to the emergency source; the Switch will retransfer the load when normal is again in proper operating condition. Accessories permit delayed transfer to emergency and retransfer to normal in order to attain system stabilization before the selected source assumes the load.

**Important announcement** . . . *new ASCO plant now being built in Florham Park, N. J., will double production capacity and greatly extend the range of our research, product development and services.*

Automatic Switch Co.
385E Lakeside Avenue, Orange, N. J. • ORange 2-5300

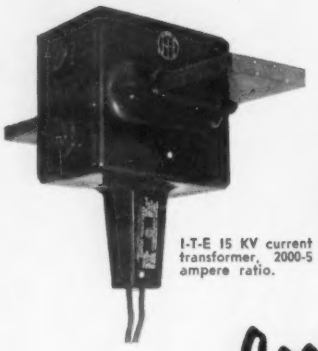
ASCO

For more information circle 41 on reader service card.



Circuit Breaker Company

# Instrument Transformers



I-T-E 15 KV current transformer, 2000-5 ampere ratio.

I-T-E 15 KV current transformer, WYE connected 14,400-110 V. ratio.

## Cast in HYSOL 6800 Epoxy Casting Resin

HYSOL 6800 has proved to be the best and most economical epoxy casting resin for I-T-E Instrument Transformers, in an exclusive process developed by I-T-E.

When compared to other epoxies, HYSOL 6800, a highly filled hot melt, offers these outstanding features:

- **Meets the requirements of Specification MIL-I-16923B, Types B and C**
- **Improved thermal shock resistance (—40°C to 130°C)**
- **High dielectric strength**
- **Low coefficient of linear thermal expansion**
- **Superior mechanical shock stability**
- **Self-extinguishing properties**
- **Good chemical resistance**
- **New economies**

Using HYSOL 6800, transformer design engineers have found they can achieve reduction in size and streamlined appearance heretofore impossible.

Houghton Laboratories manufactures complete lines of Electrical Insulating Materials, Adhesives and Sealants, Tooling Materials and cast products as rod, sheet and tube.

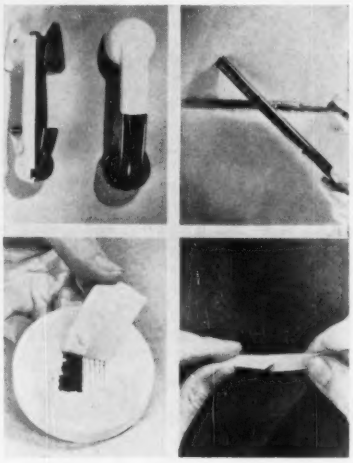
PROGRESSIVE PRODUCTS THRU CHEMICAL RESEARCH
HYSOL
Product of HOUGHTON LABORATORIES, INC.

**HOUGHTON LABORATORIES INC.**
OLEAN, NEW YORK
*In Canada*
HYSOL (Canada) LTD., TORONTO, 17

▲ Circle 42 on the card.

## Industrial Notes

(*Continued from page 38A*)



normally associated with Bakelite epoxy resins. Air-dried pieces can be handled in about two hours. The fast cure means that the bottleneck at drying ovens can be eliminated or at least lessened. The possibility of curing with low or no heat opens up the fields of precision parts to color. The new enamel can be matched to any color or gloss. Previously molders had to shut down molding machines and clean them for every short run in a particular color. They can now keep the big machines running continuously and do all the switching at the spray booths where color changes are easier to negotiate. In addition, an inventory of enamels is neither so expensive nor so cumbersome as an inventory of colored raw materials. Color range is now limited only by the user's stock of enamels.

## NEW PRODUCTS

**POC Bushing.** A series of new high voltage bushings for transformers and circuit breakers at operating voltages of 15, 23, 34.5, 46, and 69 kv is announced by the Lapp Insulator Company, Inc. Bushings 23 kv through 69 kv conform with current American Standards Association-National Electrical Manufacturers Association Standards. The bushing is a completely sealed paper-oil condenser (POC) type design with the condenser core entirely surrounded by oil and enclosed in a rugged porcelain-metal housing. Springloaded gaskets seal the assembly and protect the bushing from leakage and moisture. The bushing has no exposed core. The lower end of the core, below the aluminum ground sleeve, is covered permanently with a nontracking porcelain housing. This protects the core from deterioration by sealing out contamination and moisture. Bushings are radio and television interference free at rated voltage, have a significantly

(*Continued on page 68A*)

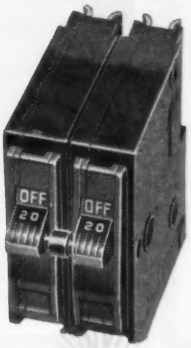
Something NEW Has Been Added To—

# QO—FINEST BREAKER EVER BUILT!

## 1-POLE

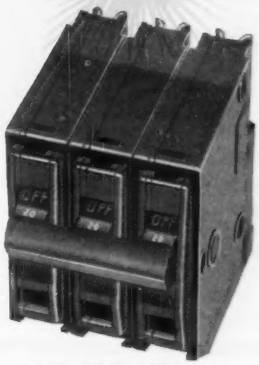
15-50 Amps

## 2-POLE




15-70 Amps

## 3-POLE



15-50 Amps

**ONE, TWO and THREE POLES GO ANYWHERE—UNLIMITED!**

**Square D's NEW 3-pole QO crashes the 3-phase price barrier!**

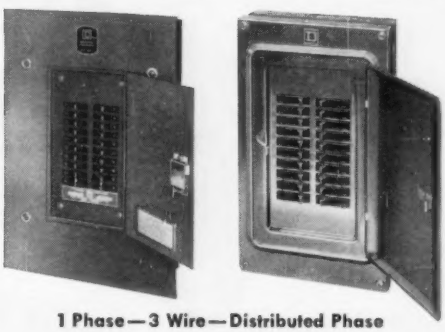
**Square D's 2-pole QO Now extended to 70 Amperes for heavier loads!**

**QO FEATURES**

- One size per pole. No space penalty
- Plug-in mounting. No time-wasting screws
- Silver-plated connections equal to best bolted design
- Switches like a "T" rated switch
- Temperature-corrected. No nuisance tripping
- Meets Federal Spec WP-131A—Class A
- Box lugs on line, load and neutral
- Rejection "ears" prevent overprotecting mistakes
- **NO CALL BACKS**

***Write for QO Bulletin. Address Square D Company, 6060 Rivard Street, Detroit 11, Michigan.***

**SAME BREAKER...PANELBOARDS & LOADCENTERS**



1 Phase—3 Wire—Distributed Phase
3 Phase—4 Wire—Distributed Phase
**2 THROUGH 42 CIRCUITS**

**NOW...EC&M PRODUCTS ARE A PART OF THE SQUARE D LINE!**

**SQUARE D COMPANY**

# STAVOLT
POWER
RECTIFIERS

30 Standard
U. L. Approved
Models

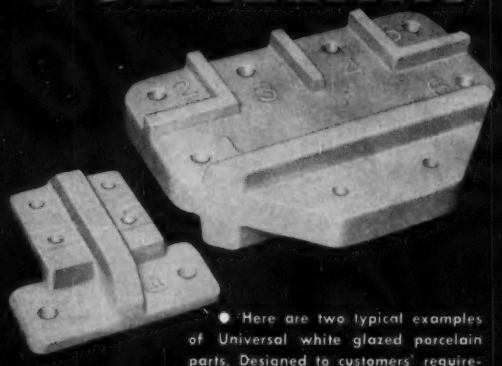
Mag-Amp Control
Stable, Fast
15 to 1500 amps

- Stationary or Mobile Types
- For Hangars, Air Fields, Missiles
- For Factories and Labs

*Write for interesting information to*
**CHRISTIE ELECTRIC CORP.**
Formerly McCOLPIN-CHRISTIE CORP.
*27th Year of Rectifier Manufacturing*
3410 W. 67th St., Los Angeles 43, Calif.

▲ Circle 44 on the card. ▼ Circle 45

# WHITE GLAZED PORCELAIN



● Here are two typical examples of Universal white glazed porcelain parts. Designed to customers' requirements these pieces utilize bosses to prevent flashover of high voltage connections. These units are made to close dimension tolerances, and have a uniform body density. Arcing will not char them, nor will they be affected by chemical fumes, moisture, heat or cold.

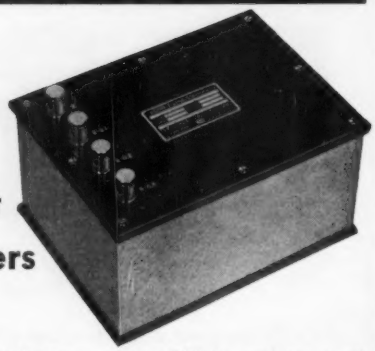
If you need trouble-free insulators, send your specs to Universal.

**THE UNIVERSAL CLAY PRODUCTS CO.**
1560 EAST FIRST STREET — SANDUSKY, OHIO
TRADE MARK

▲ Circle 46 on the card. ▼ Circle 47

# You can rely upon KNOPP Standard Burden Sets...

when testing instrument transformers



The Knopp Standard Burden Sets offer burdens of reliable accuracy and stability and burdens that possess a freedom from stray fields and harmonics.

Type BSC-5 provides in one unit all three ASA standard burdens for current transformers for metering service, i.e., B-0.1, B-0.2, and B-0.5. For potential transformers (120-v secondaries), two sets are offered. The three burdens, W, X, and Y, are combined in Type BSP-6; and the standard burden Z is supplied in Type BSP-7, two of which can be used in parallel to obtain ASA burden ZZ. Accuracy of resistance and inductance values within 0.5 per cent.

For full details about the Knopp Standard Burden Sets, write today.

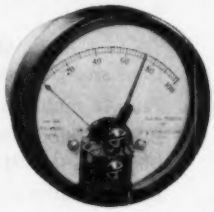
**KNOPP INC.**
4287 Holden St., Oakland 8, Calif.

# NEW METER-RELAYS
## FROM 0-5 MICROAMPERES - UP

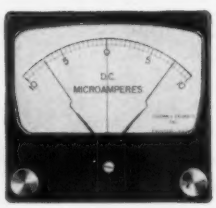
Ruggedized-Sealed—Black Bakelite—Clear Plastic Cases

*D'Arsonval indicating meters with built-in locking contacts for sensitive and accurate control or alarm*

TRIP POINT ADJUSTABLE to any point of scale arc. Sensitive to changes as little as 1%. One contact carried on moving pointer. The other on an adjustable pointer. When two pointers meet, contacts close and lock. Holding coil is wound directly over moving coil, locking action is electro-magnetic. Reset can be manual or automatic. Spring action in contacts kicks them apart forcefully.



Model 255-C, Single Contact, High Limit, 0-10 Volts DC $42.50




Model 461-C, Double Contact 10-0-10 Microamps DC $83.25

**Ranges** from 0-5 microamperes or 0-5 millivolts up, full scale. Temperature ranges from 0-300°F. (10 ohms external) have bimetal cold junction compensation. **Standard Contact Rating** 5 to 25 milliamperes DC. Can be built up to 100 milliamperes DC.

**Ruggedized-Sealed** metal cases are 2½", 3½" and 4½" round, shock-mounted, gasket-sealed.

**Black Bakelite** case, 4½" rectangular. **Clear Plastic cases** are 2½", 3¾", and 4½" rectangular. Maximum visibility and lower cost.

Panel meters and indicating pyrometers are also available in ruggedized-sealed, black bakelite or clear plastic cases. New 40-page catalog lists prices and specifications for meter-relays, meters, pyrometers and automatic controls using meter-relays. Write for Catalog 4-A, **Assembly Products Inc., Chesterland 60, Ohio.** HAmilton 3-4436 (West Coast: Desert Hot Springs 60, Calif. Phone: 4-3133 or 4-2453).

**Booth 106-7, Automation Show, Nov. 26–30, Trade Show Bldg., N. Y. C.**

# Save As Much As Half . . .
# Get Finest Protection . . .
# with THOREX ARRESTERS

You can build a 230-kv Thorex lightning arrester on no more than these small bases. You don't need any overhead or side external support. This is all there is to it!

What do these simple bases cost compared to the expense of designing, fabricating and erecting special steelwork? In other words, consider the ultimate low price of a Thorex arrester--sometimes hardly more than *half the installed cost* of supported types.

And look at the simple, unobstructed, columnar form of the Thorex. It takes substantially less station "real estate" and reduces length of leads to protected equipment--a valuable asset.

With low cost and convenience of the Thorex goes the best combination of basic protective characteristics you can buy in a lightning arrester today.

*Save money with no penalty--actually a premium--by protecting your major apparatus with Thorex lightning arresters.*

**Ohio Brass**

**MANSFIELD OHIO, U.S.A.**

4632-H



For more information circle 48 on reader service card.

# Solve Distribution Problems
## with SORGEL Substations

### "Packaged" Units for Indoor Installations

**Speeds Expansion and Earlier Production.** SORGEL Substations are shipped complete in one or more factory-assembled units, on a substantial steel base, completely wired and tested, ready for installation and final connection. This saves the extra expense of buying separately the transformers, switches, fuses, insulators, circuit breakers, and other accessories; thereby also saving the extra labor cost and trouble when assembling and connecting on the job.

**Flexibility for Future Conditions.** Being all self-contained in a single unit, the Substation can be readily moved from one location to another.

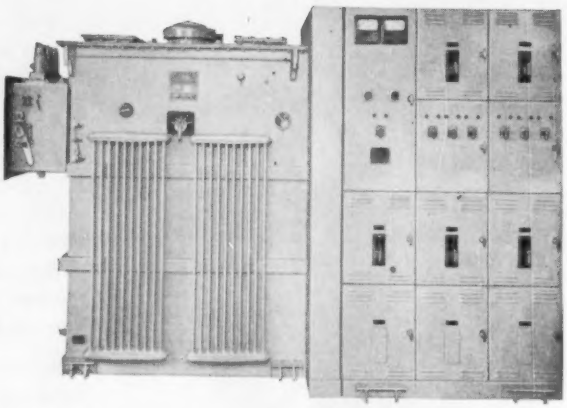
**Saves Copper.** The Substation can be placed near the load center, so that shorter secondary cables and smaller primary lines can be used. Improved voltage regulation and reduced line drop.

**Reduces Costly Power Interruption.** By locating the Substation at or near the load center, it restricts the power interruption to that area. Other areas, not affected, can continue operation.

**Years of Continuous Hard Service.** The rugged construction, liberal design, expert craftsmanship, sound engineering, all embodied in SORGEL transformers, have given years of continuous severe service.

**Types.** Either dry-type or Askarel-cooled transformers are available with any type or make of switchgear, or from any substation manufacturer.

**SORGEL transformers are particularly adaptable for indoor installations; in hospitals, libraries, schools, institutions, office buildings, and other structures where low sound levels are an important factor.**

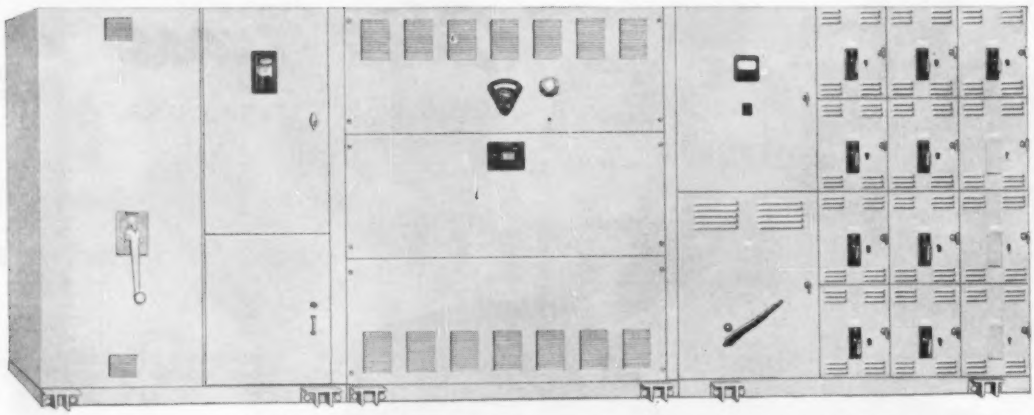


500 Kva, 13,800 volt Askarel-cooled SORGEL transformer, with primary liquid filled switch, secondary meters, and circuit breakers.

### Engineered to meet your exact requirements

Not necessary to design or change your installation to fit a "standard"

**Sizes up to 3000 Kva.**
**All voltages up to 15 KV.**



2000 Kva 3-phase, 13,200 volts air cooled dry-type transformer, with primary switchgear, metering and secondary breakers.

*Sales Engineers in Principal Cities*

**SORGEL ELECTRIC CO., 846 West National Ave., Milwaukee 4, Wisconsin**

*40 years' experience in the development, manufacturing and application of transformers*



For more information circle 49 on reader service card.

If you're expecting to read another offer of career opportunities presented on a silver platter, together with a certified rosy future neatly packaged in Fate-proof plastic—stop right here.

On the other hand, if you realize that all the bright promises and special inducements in the world cannot alter the fact that hard work, ability, and the drive to apply them are the things that make and seize real opportunities—you'd do well to read on.

Don't get the idea, because of the foregoing, that we underrate ourselves in any way. Quite the contrary. We know that our work—design and development of nuclear weapons—is as important as any being done today. We know that our working conditions and employee benefits are second to none. We know that we provide real opportunities for growth and advancement—for qualified people who have what it takes. We know, too, that living conditions at our locations—in terms of climate, housing, schools, recreation, and cultural facilities—are hard to match anywhere. At the same time, we know that it's up to you to decide whether or not you agree with us. We also have the idea that it's up to you to convince us of your ability.

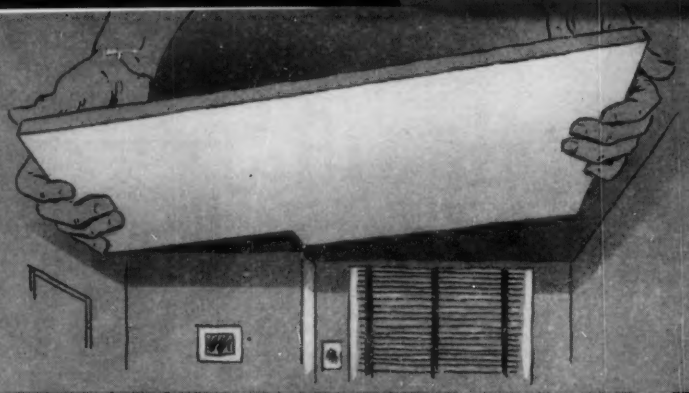
If you'd like to know more about us—our work, our background, and both our laboratories, one in Albuquerque and one near San Francisco, we'll be happy to send you our illustrated brochure that tells the whole story. Just write to Staff Employment Division 551.

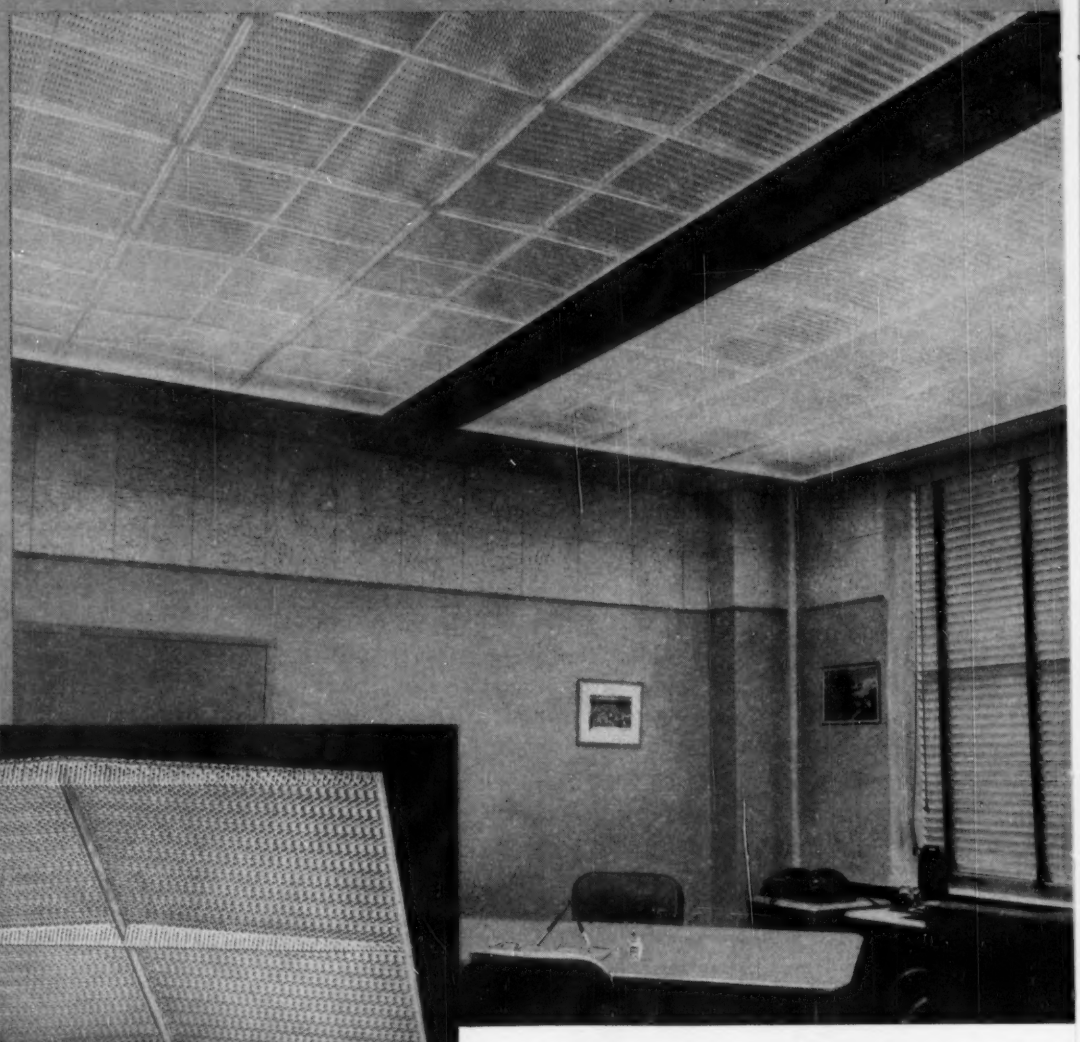
SANDIA CORPORATION

ALBUQUERQUE, NEW MEXICO

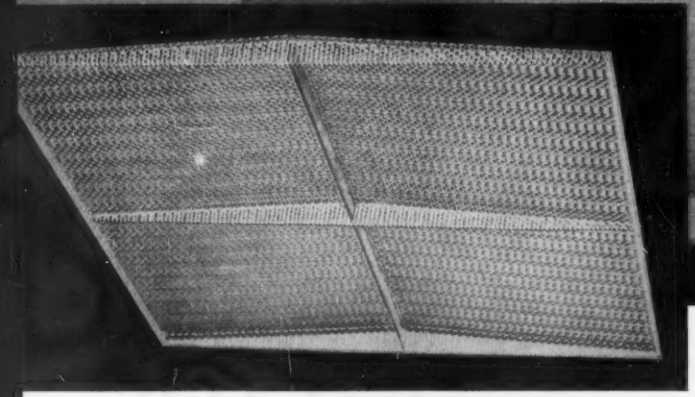
*Holophane Engineers lifted the top off this room*

*and inserted the "sky" in the ceiling...*





No. 6024
PRISMALUME*
CONTROLENS*
2-Foot Sq. (Approx.)



Whether for 2-foot-wide troffers of any length . . . or for large panels as shown above . . . the new HOLOPHANE No. 6024 PRISMALUME* is another tremendous step forward! . . . It produces maximum quantity of controlled light which provides complete visual comfort . . . Recommended for better fluorescent illumination of offices, showrooms, laboratories, stores, schools,—almost every form of modern installation...Write for detailed engineering data on this remarkable new Holophane development.

*For Better Lighting* Holophane *... Be Specific*

# HOLOPHANE COMPANY, INC.

*Lighting Authorities Since 1898*

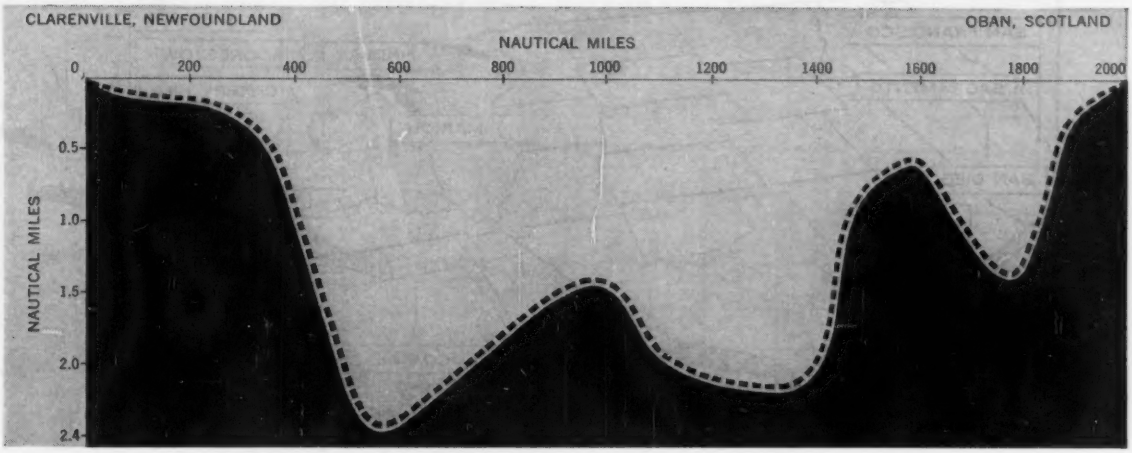
342 MADISON AVENUE, NEW YORK 17, N. Y.

rademark

THE HOLOPHANE CO., LTD., THE QUEENSWAY, TORONTO 14, ONT.

**For more information circle 50 on reader service card.**

# A TRIUMPH OF TELEPHONE TECHNOLOGY



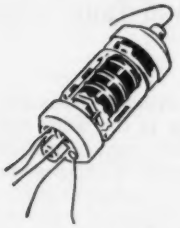

Contour of ocean bed where cable swiftly and clearly carries 36 conversations simultaneously. This is deep-sea part of system – a joint enterprise of the American Telephone and Telegraph Company, British Post Office and Canadian Overseas Telecommunications Corporation.

A great new telephone cable now links North America and Europe—the first transoceanic cable to carry voices.

To make possible this historic forward step in world communications, Bell Laboratories scientists and engineers had to solve formidable new problems never encountered with previous cables, which carry only telegraph signals.

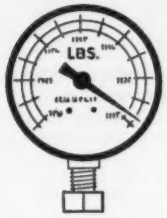
To transmit voices clearly demanded a much wider frequency band and efficient ways of overcoming huge attenuation losses over its more than 2000-mile span. The complex electronic apparatus must withstand the tremendous pressures and stresses encountered on the ocean floor, far beyond adjustment or servicing for years to come.

Here are a few of the key developments that made this unique achievement possible:

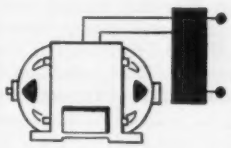


More than 300 electron tubes of unrivaled endurance operate continuously, energized by current sent from land.

Precisely designed equalizing networks and amplifiers compensate for the loss in the cable every 40 miles and produce a communication highway 144 kc. wide.




A unique triple watertight seal protects the amplifiers from pressures as high as 6500 pounds per square inch.



Power supplies of exceptional reliability send precisely regulated current along the same coaxial that carries your voice to energize the amplifying units.

**BELL TELEPHONE LABORATORIES**

*World center of communications research and development*



**For more information circle 51 on reader service card.**

plus

WORLD-WIDE LOCATIONS

# You can SELECT at RCA!

## ...New Opportunities...17 + Locations...One Best For You And Your Family

**Can anyone but RCA offer you a choice of locations like this?**
At Camden, Moorestown or Cherry Hill, you enjoy cultural advantages of Greater Philadelphia, live at moderate cost in pleasant suburban communities. Waltham offers at-home opportunities for New England engineers. Four ideal West Coast locations. Harrison borders on Greater New York. Lancaster, Marion and Findlay have small-town advantages. There's pleasant year-round outdoor living in Cocoa Beach, on Florida's central east coast. RCA Service Company and International Division assignments include ideal locations in the United States, and wherever RCA electronic equipments are installed and serviced throughout the world.

**Individual Recognition—**
RCA organizes engineering activities into groups small enough to allow broadest scope for your individual accomplishment. The average group has just 11 engineers. Yet, in all activities, you are supported by the entire facilities and engineering resources of RCA.

**Salaries—**
RCA engineering salaries average measurably higher than other companies' in the field. Intermediate engineers, $5000-$8500; senior engineers, $8500-$15,000; staff and supervisory salaries open.

**Advancement—**
Scheduled, objective appraisal of your work speeds promotion. Professional and financial progress is just as sure as your achievements make it.

**Professional Status—**
RCA bases world leadership in electronics on the abilities of exceptional men at every organizational level. Many have notable engineering and scientific reputations. You work in day-by-day association with men of this caliber.

**Benefits—**
There's a complete program at RCA. A very liberal Tuition Refund Plan. Company-paid life, sickness and accident, hospital-surgical insurance for you and your family. Modern retirement plan. Relocation expenses paid. Suggestion and patent awards.

# *Now, Pinpoint Your Future*

## ...Here are the Opportunities!
## ...Here are the Locations!

| FIELDS OF ENGINEERING ACTIVITY | | MANAGERS | TYPE OF DEGREE AND YEARS OF EXPERIENCE PREFERRED | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Electrical Engineers | | | Mechanical Engineers | | | Physical Science | | | Ceramics Glass Technology Metallurgy | | |
| | | | 0-2 | 2-3 | 4-15 | 0-2 | 2-3 | 4-15 | 1-2 | 2-3 | 4-15 | 1-2 | 2-3 | 4-15 |
| • ***SYSTEMS*** *(Integration of theory, equipments and environment to create and optimize major electronic concepts.)* | **AVIATION ELECTRONICS • CONTROLS** | | W | W | W C | W | W | W C | W | W | W C | | | |
| | **DIGITAL DATA HANDLING DEVICES** | M C | | M C | M C | | C | C | | C | C | | | |
| | **MISSILE ELECTRONICS • RADAR** | M W | W | M W X | M W X | W | M W | M W | W | M W X | M W X | | | |
| | **INERTIAL NAVIGATION** | | | W | W | | W | W | | W | W | | | |
| | **COMMUNICATIONS** | | | C N | C N | | | | | | C N | | | |
| • ***DESIGN • DEVELOPMENT*** **MISSILE WEAPONS SYSTEMS**—Planning and Design—Radar—Fire Control—Servo Mechanisms—Computers | | M | M X | M X | M X | M | M | M X | M | M X | M X | | | |
| **AVIATION ELECTRONICS**—Radar—Computers—Servo Mechanisms—Shock and Vibration—Circuitry—Remote Control—Heat Transfer—Sub-Miniaturization—Automatic Flight—Automation—Transistorization | | W C | W C X | W C X | W C X | W C | W C X | W C X | W C X | W C X | W C X | | | |
| **RADAR**—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control—Information Handling—Displays | | M C | M C X | M C X | M C X | M C X | M C X | M C X | M C X | M C X | M C X | | | |
| **COMPUTERS**—Systems—Advanced Development—Circuitry—Assembly Design—Mechanisms—Programming—Digital Data Handling Devices | | | C | C X | M C X | C | C X | M C X | C | C | M C | | | |
| **KINESCOPES (B & W and Color), OSCILLOSCOPES**—Electron Optics—Instrumental Analysis—Solid States (Phosphors, High Temperature Phenomena, Photosensitive Materials and Glass to Metal Sealing) | | | L | L Y | L Y | L | L Y | L Y | L | L Y | L Y | L | L Y | L Y |
| **RECEIVING TUBES**—Tube Design—Test and Application Engineering—Chemical and Physical Development—Methods and Process Engineering—Advanced Development | | | H | H | H | | H | H | | H | H | | H | H |
| **SEMICONDUCTORS**—Transistors—Semiconductor Devices—Materials | | | V | V | V | V | V | V | V | V | V | V | V | V |
| **MICROWAVE TUBES**—Tube Development and Manufacture (Traveling Wave—Backward Wave—Magnetron) | | H | | H | H | | H | H | | H | H | | H | H |
| **GAS, POWER AND PHOTO TUBES**—Photosensitive Devices—Glass to Metal Sealing—UHF and VHF—Power | | | L | L | L | L | L | L | L | L | L | L | L | |
| **COMMUNICATIONS**—Specialized Systems—Microwave—Mobile—Aviation—Audio—Propagation Studies—Acoustics—Transducers | | | C N | C N | C N | | C | C | C N | C N | C N | | | |
| **BROADCAST AND TV**—Monochrome and Color Studio Equipment—Cameras—Monitors—High Power Transmitters | | | C | C | C | C | C | C | C | C | C | | | |
| • ***SYSTEMS APPLICATION*** *(Evaluation and Planning—Design and Development—Modification—Specification)* | | | | | | | | | | | | | | |
| **MISSILE TEST INSTRUMENTATION** (Data Acquisition and Processing)—Radar—Telemetry—Timing—Communications—Optics—Computers | | F | F S | F S | F S | F S | F S | F S | F S | F S | F S | | | |
| **RADAR**—Airborne—Surface—Shipboard—Sonar—Fire Control | | F | F S | F S | F S | F S | F S | F S | F S | F S | F S | | | |
| **COMMUNICATIONS**—Radio—HF—VHF—UHF—Microwave—Telephone—Teletype—Telegraph Terminal Equipment—Wave Propagation | | F I | F S I | F S I | F S I | F S | F S | F S | F S | F S | F S | | | |
| • ***MACHINE DESIGN*** **Mechanical and Electrical—Automatic or Semi-Automatic Machines** | | | L | L | | L | L H Y | C H Y | | L | L | | | |

**Locations: C**—Camden, N.J. **F**—Cocoa Beach, Fla. **H**—Harrison, N.J. **I**—Clark, N.J. (periodic foreign assignments). **L**—Lancaster, Pa. **M**—Moorestown, N.J. **N**—New York, N.Y. **S**—RCA Service Co. (Cherry Hill, N.J.; Alexandria, Va.; Tucson, Ariz.; San Diego, Sacramento, San Francisco, Calif., Foreign Assignments). **V**—Somerville, N.J. **W**—Waltham, Mass. **X**—West Los Angeles, Calif. **Y**—Marion, Ind.

Please send resume of education and experience, with location preferred, to:

**Mr. John R. Weld, Employment Manager**
**Dept. A-14L, Radio Corporation of America**
**30 Rockefeller Plaza, New York 20, N.Y.**

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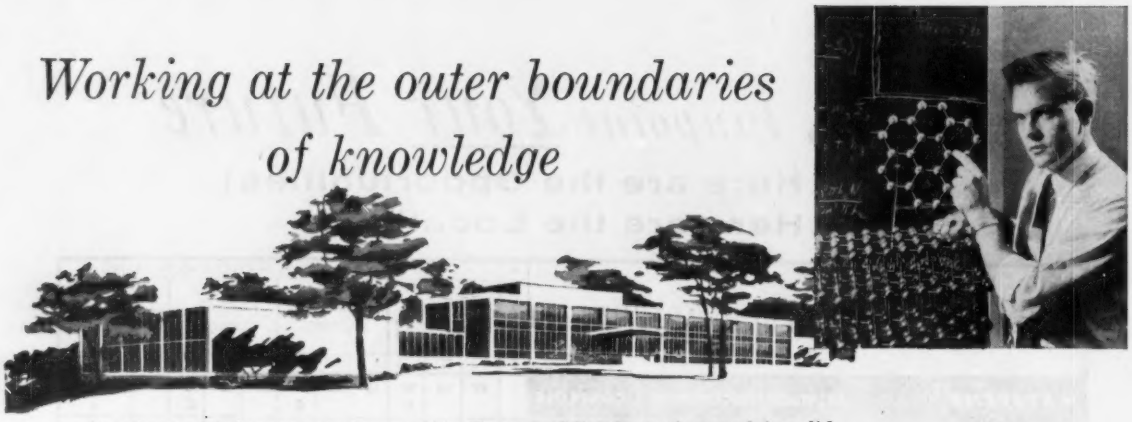
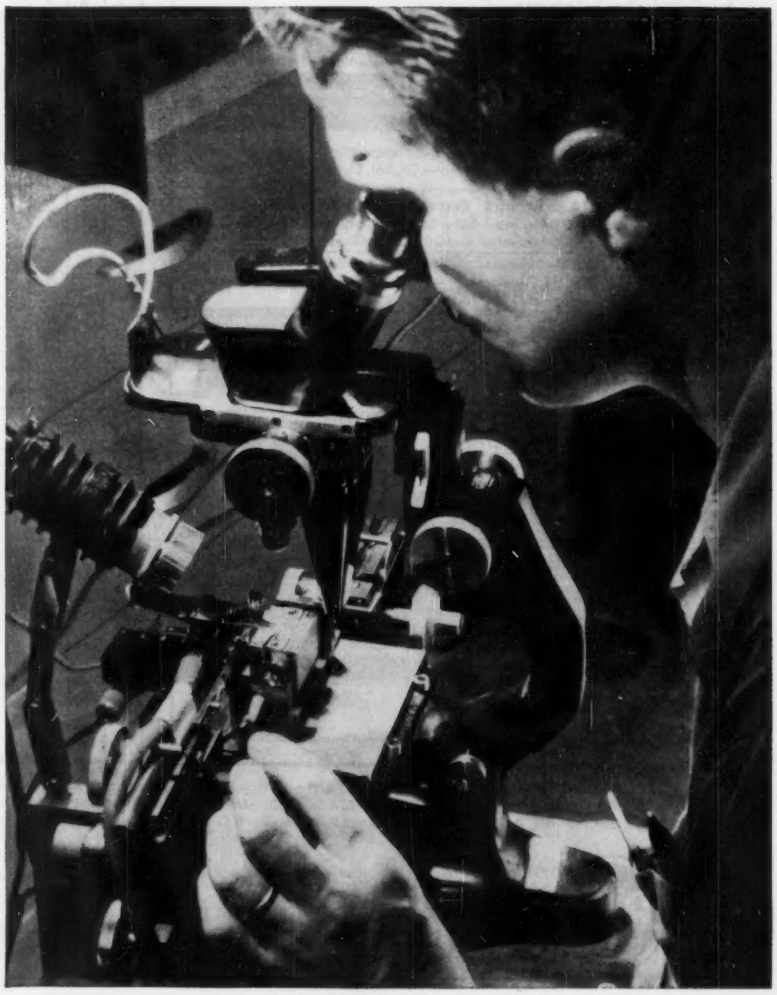
# *Working at the outer boundaries of knowledge*



**New Research Laboratories in Parma, Ohio.** To expand its pioneering work in solid state and chemical physics, National Carbon Company has enlarged its staff of scientists and provided them with an ideal laboratory setup for creative work. Typical of their pioneer experimentation is current work on the "fuel cell" — a new type of battery for producing electricity directly from gases, such as hydrogen and oxygen. This is part of a far-ranging research program on all types of batteries and their carbon components.

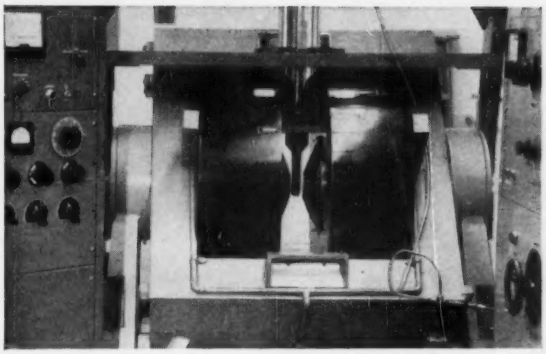
**New**



**Mechanized tweezers handle graphite crystal.** To make it into a proper experimental guinea pig, the fragile crystal must be painstakingly cut and mounted so that electrical flow can be measured along the unique crystalline directions of graphite. Experiments with pure graphite crystals are important because all materials which we know as carbon and graphite are basically composed of the same graphite crystals being prepared here. Tremendous differences in electrical behavior and other vital properties can be traced to variation in size and arrangement of the graphite crystals in carbon products.



For more information circle 52 on reader service card.



**Graphite must pass good-conduct test.** A tiny graphite crystal is chilled to within one degree of absolute zero, then held between poles of a powerful electromagnet while electrical conductivity is measured in each crystalline direction — one of many ways to learn more about carbon.

**The sky's the limit for brush tests.** This experimental chamber simulates atmospheric conditions from sea level up to stratospheric heights of ten miles or more, with controlled variations of temperatures and humidity, for development of carbon brushes to meet specific operating needs.

# break-through in carbon physics research

***promises future advances in carbon brushes for industry***

One more barrier is down. And science strides forward in the age-old quest for deeper knowledge of carbon, one of nature's more complex puzzles.

This barrier—the inability to get large graphite crystals pure enough for experimental needs—has now been overcome by researchers of National Carbon Company. Their new annealing techniques, which remove impurities from large graphite crystals, also eliminate imperfections and weaknesses in the crystalline structure.

Several research teams at the new Parma laboratories are exploiting this break-through of science. The purified crystals are being subjected to a variety of experimental tortures—electrical, magnetic and thermal. Fundamental facts about the behavior of the single graphite crystal are being gathered and pieced together like jigsaw cutouts—building up a more complete and systematic picture. In this way, our scientists will be better able to *predict* the properties of new carbon and graphite materials.

The work on single graphite crystals is only one phase of a broad research program in carbon physics. Industrial users of carbon brushes or other carbon and graphite products, will share in the gains from this work of science at the outer boundaries of knowledge. Write for new booklet titled "Research," telling more about the work at the new Parma laboratories.

*Look to* **NATIONAL CARBON**
*for leadership in carbon and graphite products*

**NATIONAL CARBON COMPANY** • **A Division of Union Carbide and Carbon Corporation** UCC **30 East 42nd Street, New York 17, N. Y.**
*Sales Offices:* Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco. *In Canada:* Union Carbide Canada Limited, Toronto

*another example* *of exciting work at los alamos...*

## DETECTION OF THE FREE NEUTRINO

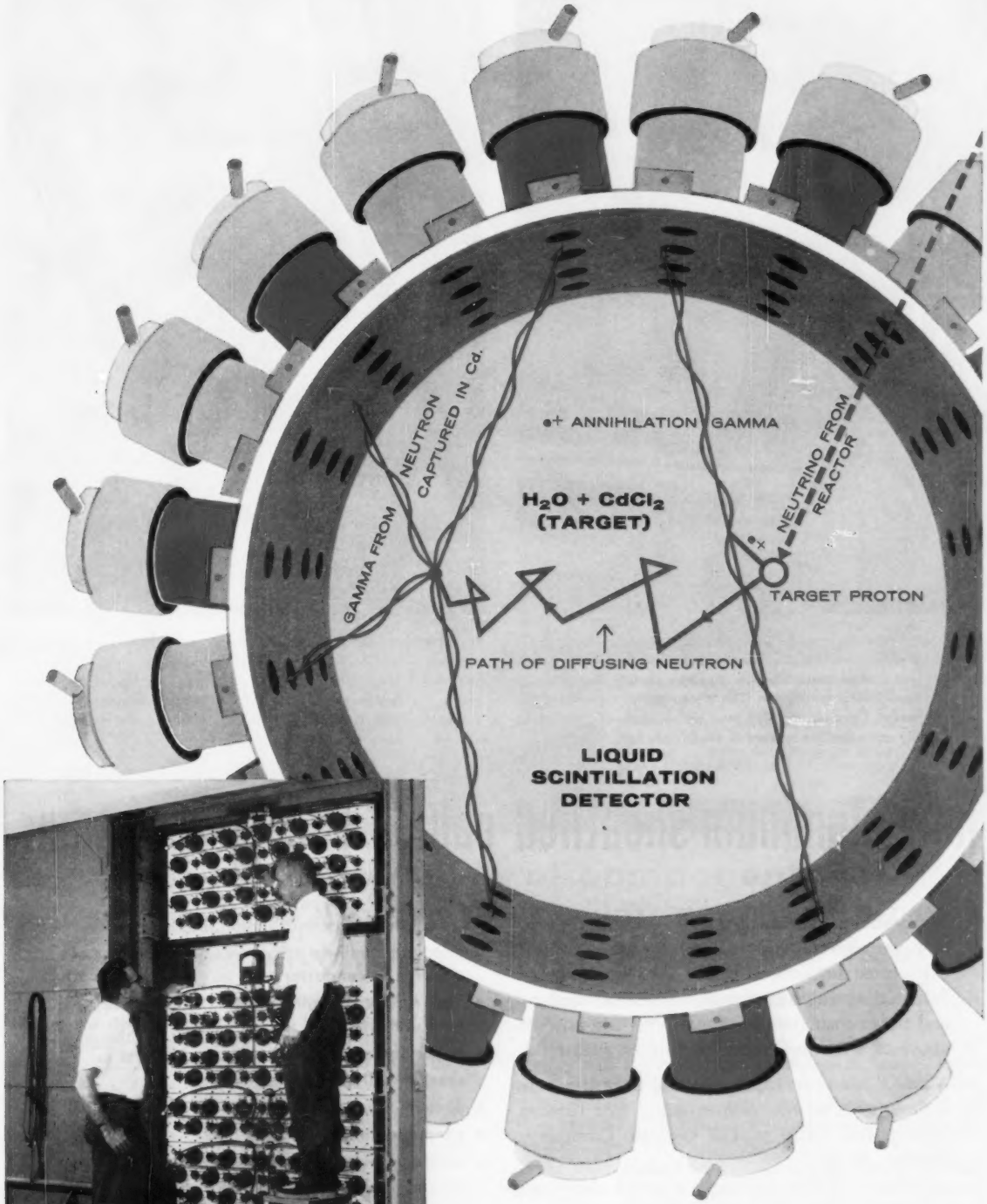
Working with the most modern technical equipment, a team of scientists of the Los Alamos Scientific Laboratory has recently demonstrated the existence of the free neutrino*. Such an experiment is the culmination of work on the frontiers of physics, chemistry and electronics, in which the very latest advances in nuclear theory, scintillator development, and electronics are combined to achieve an important milestone in scientific progress. Teamwork of this kind is typical at the Los Alamos Scientific Laboratory, which welcomes applications for employment from qualified scientists and engineers. For more information, write:

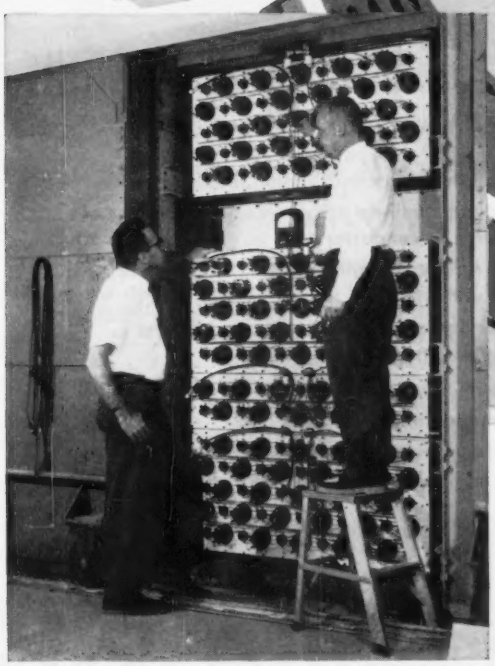
*Director of Scientific Personnel*
*Division* 1414

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

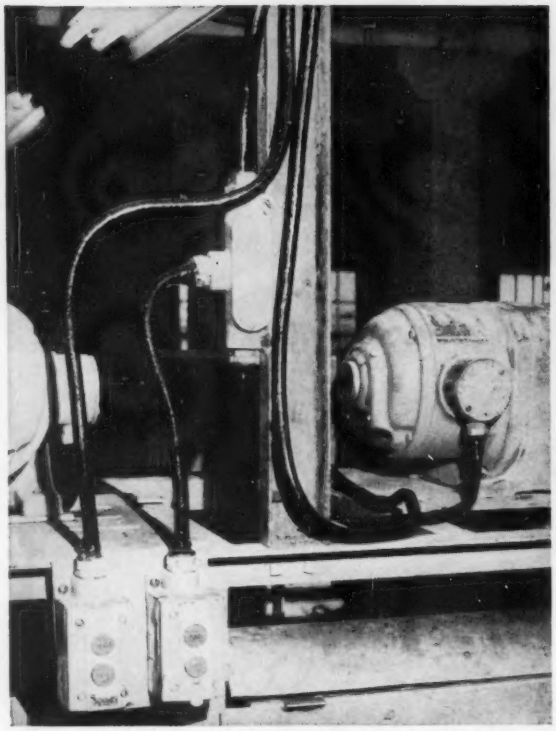
*C. L. Cowan, Jr., F. Reines, F. B. Harrison, H. W. Kruse, A. D. McGuire, *Science* 124, 103 (1956)

*Los Alamos Scientific Laboratory is operated by the University of California for the U. S. Atomic Energy Commission.*

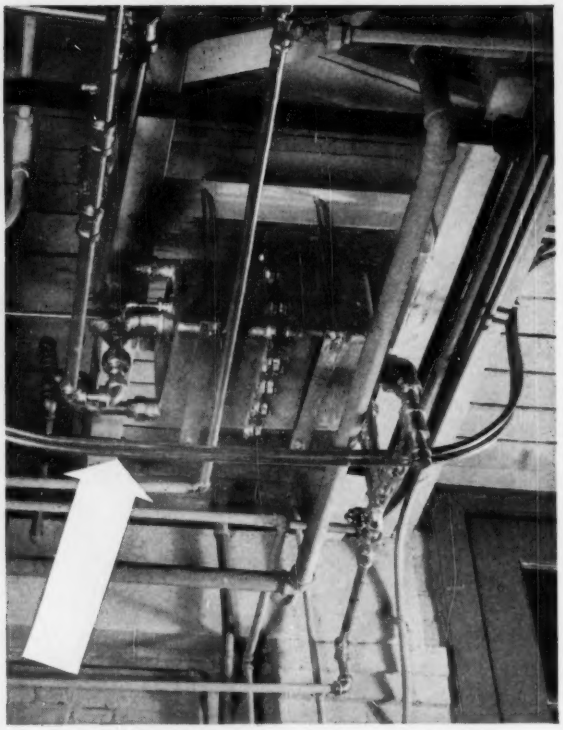


*Bank of photomultiplier tubes used in the neutrino experiment.*



Simple terminations—aluminum-sheathed cables are as simply terminated as conventional rubber-insulated control cables. For leads to motors and control apparatus, an aluminum sheath also provides a neat, space-saving installation. This photo shows optional Okosheath Protective Covering applied over aluminum sheath to combat an extremely corrosive atmosphere in this installation.



Easy installation—aluminum-sheathed cable is inherently rigid, yet see how easily it can be installed around pipes, heat exchangers, and other obstructions. Conduit is eliminated. Regular conduit clamps give all the support necessary for overhead installations. Note that aluminum sheath is seamless, providing a permanent moisture-proof barrier.

# new aluminum-sheathed cables eliminate conduit

Many advantages are obtained from the addition of a *seamless* aluminum sheath over standard cable constructions. Virtually any Okonite cable —including rubber, plastic, varnished cambric and paper-insulated constructions—can now be obtained with an Okonite aluminum sheath.

A list of the advantages resulting from this new technique is in the next column. For further information, write to The Okonite Company, Passaic, N. J.

- **no conduit—cuts installation time and costs**
- **eliminates pulling problems and possibility of damage to conductors**
- **high tensile strength and rigidity, yet easily bent with standard tools**
- **impervious barrier to liquids and vapors**
- **mechanically strong**
- **excellent flame resistance**
- **simple terminations**
- **small diameter, light weight**

3502

OKONITE SINCE 1878 **insulated cables**



For more information circle 53 on reader service card.



Circle 54 ▶

**DC SOLAVOLT,** *shown partly disassembled here, has major components identified. It is designed for relay-rack mounting on a standard, 19" frame or for bench use. Removable handles, for convenience when portability for bench use is desired, are available as accessory equipment.*

# Unique combination of components in adjustable "DC Solavolt" regulated power supply reduces conventional size, weight, and cost

Compact size, low weight, high efficiency, and moderate price distinguish the new "DC Solavolt" from conventionally-designed, regulated, adjustable dc power supplies. These outstanding advantages have been secured by using a unique assembly of components (shown above) that occupy only 7" of height and 12¼" of depth on a standard, 19" relay rack frame.

Along with design simplicity, the "DC Solavolt" provides laboratory standards of performance:

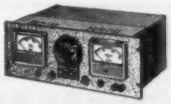
**OUTPUT VOLTAGE REGULATED WITHIN ±1%** at full load with supply voltage variations up to ±15%. (Regulation within ±1.5% at 50% load and lowest voltage setting.)

**RIPPLE VOLTAGE HELD WITHIN 0.10%** (rms) at full load and nominal input voltage.

An important feature of this adjustable dc power supply is its ability to handle transient or "pulse" loads of up to twice the full load rating of the supply. The "DC Solavolt" has no tubes to replace, requires no "compensating" or "zero" adjustments, and needs no maintenance.

Six stock models provide outputs *adjustable in voltage ranges between 5 and 400 volts and load currents up to 7 amperes.* Your local electronic distributor now has the "DC Solavolt" in stock. He will be happy to give you further, technical information.

**SOLA** *Constant Voltage* **DC POWER SUPPLIES**



**Write for Bulletin 5K-DC-245**
**SOLA ELECTRIC CO.**
**4633 W. 16th Street**
**Chicago 50, Illinois**

CONSTANT VOLTAGE TRANSFORMERS • FLUORESCENT LIGHTING BALLASTS • MERCURY VAPOR LIGHTING TRANSFORMERS
**SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414** • *NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464*
*PHILADELPHIA: Commercial Trust Bldg., RIttenhouse 6-4988* • *BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3354* • *CLEVELAND 15: 1836 Euclid Ave., PRospect 1-6400* • *KANSAS CITY 2, MO.: 406 W. 34th St., Jefferson 4382* • *LOS ANGELES 23: 3138 E. Olympic Blvd., ANgelus 9-9431* • *SOLA ELECTRIC (CANADA) LTD., TORONTO 17, ONTARIO: 102 Laird Drive, Mayfair 4554* • *Representatives in Other Principal Cities*

# NEW CASES • • NEW ADVANTAGES

## METALLIC CASES

- Tight-sealed with no rolled edges
- minimum axial case length for *MINIATURIZATION*
- surface insulated against voltage breakdown
- precision shaped for multiple stacking of cores

## PHENOLIC CASES

- Tight-sealed rigid core protection
- free from case to coil capacitance

## CERAMIC CASES

- Tight-sealed with maximum temperature endurance
- highest electrical insulation

Selection of suitable encasement will assure better uniformity of magnetic Centricore properties. Review of present core specifications to new case types should be made NOW. Write for data and prices.

**Centricores—Magnetic-engineered since 1930**

NO ROLLED EDGES

SURFACE INSULATED

TIGHT-SEALED

RIGID CORE PROTECTION

**MAGNETIC METALS COMPANY**

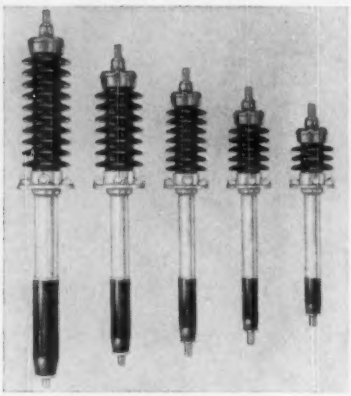
ELECTROMAGNETIC CORES AND SHIELDS

HAYES AVENUE AT 21st STREET • CAMDEN 1, NEW JERSEY

▲ Circle 55 on the card.


## New Products

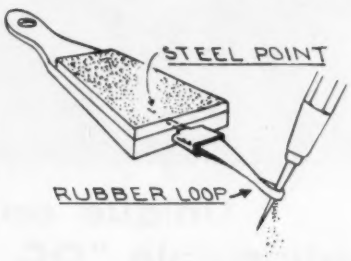
(*Continued from page 52A*)



low power factor, and are nonchanging in storage or in service. This announcement follows an extended period of research and development. The adoption of paper-oil as the insulating member is based on the fact that the highest voltage bushings and those that have the best operating records are of this type.

**Item 56 on the card.**

**Pencil Point Cleaner.** The graphite dust that remains on the pencil point after each sharpening is removed from the point by the squeegee-like action of a rubber loop. This loop is fastened to a stainless steel point which is imbedded into the end




of the sandpaper stick. When the sandpaper stick is to be discarded, the point is withdrawn and then pushed into the end of the new sandpaper stick.

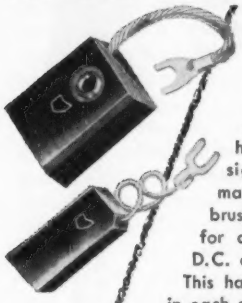
**Item 57 on the card.**

**Voltage Stabilizers.** A series of constant voltage stabilizers are claimed by Acme Electric Corporation to have several features particularly significant to equipment engineered to extremely close voltage tolerances. One example cited refers to electronic circuits where 6.3 volts are required for filament heating. The ±1 per cent voltage tolerance, and complete recovery within two cycles would generally be of no significance to the performance required. Output voltage stabilization is automatically obtained by a parallel combination of a fixed capacitance and a magnetic core inductance to provide the

(*Continued on page 74A*)

9-9431 • SOLA ELECTRIC (CANADA) LTD., TORONTO 17, ONTARIO: 102 Laird Drive, Moylan 4554 • Representatives in Other Principal Cities

# BRUSHES for D.C. Arc Welders



Ohio Brush parts numbers have been assigned to the many and varied brushes required for all makes of D.C. arc welders. This has been done in each case with the proof in hand that we have the brush that will give long trouble-free life. Laboratory control from the raw material to the finished product assures uniformity in all characteristics from order to order.

Ohio Carbon Catalog 15-A lists welders alphabetically in the manufacturers' name and numerically in model, type and amps. Your letterhead request will bring you a copy by return mail.

ORDER YOUR CARBON BRUSHES FROM A SINGLE SOURCE

THE OHIO CARBON COMPANY

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A MUST for Electrical Engineers!

1) The Art and Science of PROTECTIVE RELAYING

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Here is a valuable source of clear, up-to-date information about the essential principles of relay design and application, as well as a full and dependable reference with a new and different approach and plenty of source material. A book of practical utility, it provides basic training that will prove useful to the application of protective relaying equipment of any manufacturer. One of a series written by General Electric authors for the advancement of engineering practice. 1956. 410 pages. 244 illus. $12.00.

2) LINEAR TRANSIENT ANALYSIS, Volume II

Two-Terminal-Pair Networks; Transmission Lines

By ERNST WEBER, Polytechnic Institute of Brooklyn

A systematic, comprehensive presentation of transient phenomena in passive and active two-terminal-pair networks, in filters, and in transmission lines. Although mathematical in nature, the treatment stresses the physical background and the physical interpretation of a solution. 1956. 452 pages. 142 illus. $10.50.

3) Volume I: Lumped-Parameter Two-Terminal Networks

1954. 348 pages. Illus. $7.50.

4) POWER SYSTEM STABILITY, Volume III

Synchronous Machines

By EDWARD WILSON KIMBARK, Seattle University

This third and final volume of *Power System Stability* is a completely modern presentation of the theory of synchronous machines and their excitation systems. It discusses such effects as saliency, damping, saturation, and high-speed excitation, for a better understanding of power system stability than has previously been available. 1956. 322 pages. 155 illus. $10.00.

5) Volume I: Elements of Stability Calculations

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6) Volume II: Power Circuit Breakers and Protective Relays

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8) SPHEROIDAL WAVE FUNCTIONS

Including Tables of Separation Constants and Coefficients

By J. A. STRATTON, P. M. MORSE, L. J. CHU, J. D. C. LITTLE, and F. J. CORBATO, all of The Massachusetts Institute of Technology

This book deals with those spheroidal wave functions appropriate for prolate or oblate spheroidal boundaries. It includes a set of tables, computed, tabulated and printed automatically, which make certain calculations in applied physics, acoustics, and radar much more practicable. A Technology Press book, M.I.T. 1956. 613 pages. $12.50.

9) CIRCUIT THEORY AND DESIGN

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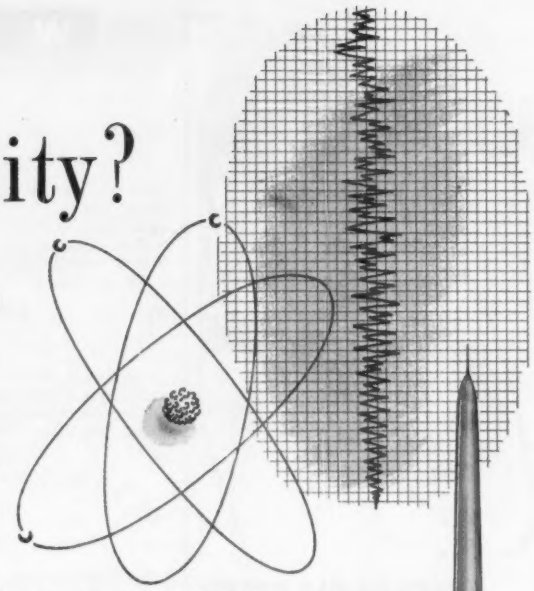
*FIRST OF A SERIES*

# What is reliability?



**Industry in the United States is becoming more and more complex... we're getting automated ... computers are computing... the missiles are flying... the digits are digitizing...**

**And the word "Reliability" takes a new and different meaning... what does it mean to you?**

It's time to stop and take a look! Ask three of your friends how they define "reliability." You'll be surprised at the different answers you receive. And when you quiz them further on how much reliability is needed in a particular product... how they would control the design and manufacture of that product to obtain the amount of reliability they want... you'll be even more surprised by the variety of the answers.

So... let's define reliability. Let's start off with a definition that is gaining the most acceptance in the technical field...

***The reliability of a particular component or system of components is the probability that it will do what it is supposed to do under operating conditions for a specified operating time.***

Looks simple enough!

But what hazards it presents! The first important challenge is that word "probability"... it takes you seriously into the field of data collection and statistical analysis. Then you check into the phrase "do what it is supposed to do"... someone must define these objectives. And, look at the "operating conditions"... pause briefly and reflect on the many different conditions under which products operate. And, finally, note the phrase "for a specified operating time"... does one normally, consciously, define reliability in terms of time?

These considerations pose problems for all of us... the manufacturers of components, those who assemble components into other products, systems personnel, designers, industrial engineers, production workers, purchasing agents, quality control... *and users!*

Let's look at the word "probability."

Picture a chain, with its successive links. Many of today's systems, simple or complex, comprise such a chain of components. However, as we all know, that chain will be only as reliable as its weakest link. And, statistically, the over-all reliability of the chain or system is the mathematical product of the reliabilities of the individual links expressed as...

***Over-all Reliability,*** $R_0 = r_1 \times r_2 \times r_3 \ldots r_n$

As an example, assume a product has a chain of 100 components in which each component has a reliability of 99 per cent... which assumes that only one out of a hundred units of each component will fail. These are relatively high standards established by past practices. But what happens? Multiplying .99 by itself one hundred times ($.99^{100}$), note that our chain of components will have a reliability of only 36.5 per cent! Two out of three of our chains would probably fail!

As another example, let's look at contacts in a multi-contact electric connector. If, for instance, we are to assemble connectors containing 25 similar contacts from a 1% defective contact population, we can expect 22% of the connector assemblies to contain one or more defective contacts! See how the multiplication of probabilities presents a major challenge to both designer and manufacturer?

But all is not lost! There is another side of the picture. With proper care, analysis, and control, our organization at Cannon has actually achieved, in special "missile quality" contacts, a known level of only $2.85 \times 10^{-3}\%$ defective... or one defective part in 35,000! Naturally, we don't achieve

For more information circle 60 on reader service card.

that with all our contacts . . . but we do try to design and manufacture the utmost in reliability required for specific applications.

However, to return to your problems and to go a step further in demonstrating "probability" of uncontrolled contacts . . . and the challenges it poses to you and to us . . . consider the case where we have three groups of contacts, each group with contacts of different sizes. Let us assume, also, that each group has different percentage defective populations and that the three groups are assembled in a 90-contact connector as follows:

50 No. 16 contacts with a population reliability of .59;
25 No. 12 contacts, reliability .60; and 15 No. 8 contacts, reliability .64.

Then . . .

$$Rc_{(90\ \text{contact connector})} = r_{\#16} \times r_{\#12} \times r_{\#8}$$

*or,*

$$Rc_{(90\ \text{contact connector})} = (.59)\ (.60)\ (.64) = .23$$

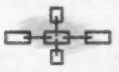
It is apparent from the above that connector contact populations must be maintained at extremely low values of percentage defective. This is of extremely vital importance if we are to produce connector assemblies which will perform satisfactorily in systems utilizing series circuitry, where the failure of one contact pair can cause failure of the entire system.

We have been talking only about *a contact* . . . just one of the many different materials and parts (such as contact pins, insulators, shells, and couplings) going into the more than 20,000 different connector and electrical items we manufacture. Think of the "product of reliabilities" rule in systems comprised of tens, hundreds, or thousands of electrical components connected by connectors such as ours. Regardless of whether they design, manufacture, sell, or use washing machines or guided missiles, everyone faces the same problem. That's why we're taking some of your valuable time to present the important subject of reliability here.

*

All of us, when we specify materials, parts or components must constantly keep in mind the (a) "probabilities," (b) what the part is supposed to do, (c) the operating conditions, and (d) the time it must operate satisfactorily. Let's see what we can do to increase reliability in relation to these four factors:

***(a) Probabilities.*** To increase the reliability of any component, and thereby the system as a whole, it is necessary to think in terms of statistical distribution of important physical properties. From field reports of failure and laboratory test results, we must first isolate those properties which most frequently cause trouble. It is then necessary to determine whether poor performance is due to lack of process control to keep the product within specified tolerance limits, whether the dollar sign has entered into the picture too far—cutting reliability down for the sake of a few cents here or there—or whether the design itself is inadequate for an end-use application. In any case, the use of the statistical approach to problem solution offers a positive method of obtaining known levels of reliability.



***(b) Definition of Function of Product.*** Each component and each system . . . both civilian and military . . . in each different field of endeavor, in each product produced, has different functions. None of us should "overbuild" . . . nor should we "under-build." We should look at our specifications closely.

***(c) Operating Conditions.*** Temperature and pressure, humidity, corrosive atmospheres, stray electric and magnetic fields, low and high frequency noise, shock and vibration . . . all must be considered plus conditions prior to product use.

***(d) Operating Time.*** This varies both for different products and different fields of application. Have you set reasonable lengths of operating time for your product or system, from the viewpoints of both usage and economics?

*

We at Cannon Electric are proud of our historical emphasis on quality and reliability. Since our inception in 1915 we have consistently adhered to a design philosophy embracing the highest quality and reliability in each Cannon Plug for the specific application for which it is to be used. *If we cannot design to that principle, we don't make it!* In manufacture, we are proud of our know-how in depth, proud of our fine quality control systems, proud of our personnel, and proud of our reliability control group. The "Cannon Credo" . . . part and parcel of the everyday life of each Cannon employee . . . is posted in all offices and all departments of all eight Cannon plants around the world. Three of its sections read as follows:

***To develop an organization of exceptional people possessed of respect for the dignity of the individual and imbued with the spirit of the team.***

***To provide a facility with which we can produce to our utmost in an efficient and pleasant environment.***

***To develop and produce products of such quality, and render such service, that we may always be proud of our efforts.***

*

Whenever *you* have an electric connector reliability problem . . . in design, engineering, production or prototype phases . . . we would welcome the opportunity of discussing it with you.

*Cordially,*

Robert J. Cannon *President*

CANNON ELECTRIC COMPANY
3208 Humboldt St., Los Angeles 31, California

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*Eight plants around the seven seas!*

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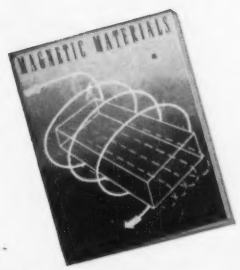


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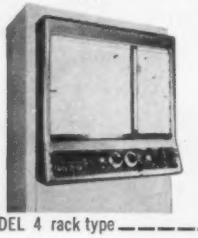

MODEL 4 rack type

Now offered in four versatile models, the Moseley AUTOGRAF X-Y recorder is a high quality, precision instrument providing economical means for plotting data quickly, easily, and accurately. It is widely used in research, development, and test laboratories where quantities of mechanical, physical and electrical data are being collected daily.

Features include ranges from 5 millivolts to 500 volts; 200,000 ohms per volt input resistance; zero set and full scale zero off-set; speeds up to ½ second, full scale; better than 0.25% accuracy.

A complete line of accessories is available for almost any data translation problem.

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VOICE COMMUNICATION PLUS Control

RFL Model 983

OPERATES OVER WIRE CIRCUIT OR MICROWAVE

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2-Way Clear Voice and Reliable Control

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Provides two, reliable frequency shift control channels at 2800 & 3000 cps isolated from voice by filters. Isolation transformers allow connection to balanced wire circuits. Interchangeable plug-in components and printed circuit boards are used in transmitter, receiver and power supply sections.

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BIBLIOGRAPHY ON TESTING OF INSULATING MATERIALS AND SYSTEMS FOR THERMAL DEGRADATION (April 1956)

This bibliography, S-87, has been prepared under sponsorship of the AIEE Committee on Dielectrics. It represents a compilation of articles dealing with, or containing in part, discussion on measurements and techniques employed for an evaluation of thermal degradation characteristics of insulation materials, systems, or capacitors. The articles have been grouped into six categories for easy reference. Price: $0.50.

Available from: Order Dept., AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, 33 West 39th Street, New York, N. Y.

11-56


## New Products

(*Continued from page 68A*)

variable capacitive current. Voltage stabilization is further improved with a compensating winding to balance the output circuit, the manufacturer states, with the magnetic circuit so designed as to provide electrical isolation between input and output circuits. This new series of constant voltage stabilizers cannot be damaged by overloading. As the per cent of overload increases above rated value, the output voltage decreases until overload increases finally results in zero output voltage. Two styles of voltage stabilizers have been designed to application requirements. The 15, 25, and 50 volt-ampere units can be supplied with the output voltages of 6.3 volts or 115 volts. Units of 100 to 500 volt-ampere capacity are available with input of 95 to 130 volts and output of 115 volts. Catalogue *CVS-308* describes performance characteristics in detail.

**Item 64 on the card.**

**Drum.** A 300-pound fiber container, reputed to facilitate the use of *X-73* ice remover and at the same time provide a minimum winter supply for small plants has been announced. Designed for easy moving by hand or power trucks, the drum is 24 inches wide. Consequently, *X-73* can be readily shoveled or scooped from it. Another advantage of the drum by the Monroe Company, Inc., is that it permits pressure packing, thus greatly reducing the absorption of air moisture. This makes possible the storage of *X-73* over extended periods without deterioration. *X-73* chemical pellets are applied by scattering lightly over icy surfaces. At temperatures from 0 to 20 F, it is reputed to attain thawing capacity up to 30 times that of salt. *X-73* is suitable for shoveling, hand spreading, and use with either mechanical or motorized spreaders. It is recommended for use on loading docks, parking lots, steps, walks, drives, and highways. Other common usages are for keeping drains and gutters open and providing quick traction under spinning auto wheels. In addition to the 300-pound drums, *X-73* is also offered in 100-pound drums. Ton and larger lots are shipped in sturdy, lined 100-pound bags. The product can also be transported in dump trucks or covered hopper cars.

**Item 65 on the card.**

**"Handy" Resuscitator.** In critical emergencies, when the victim of a mishap may be seconds away from death, the portable-model "Handy" resuscitator can often avert tragedy. It has proved a lifesaver for those stricken by heart attacks or overcome by suffocation, as in drowning, carbon monoxide poison, electric shock, strangulation, and asthma. The resuscitator is dependable, simple to operate, and so light that it can be carried by one person. As a resuscitator, it automatically inhales and exhales for the patient being treated and automatically adjusts to his lung capacity. As an aspirator, it furnishes sufficient suction to clear water, mucus,

(*Continued on page 76A*)

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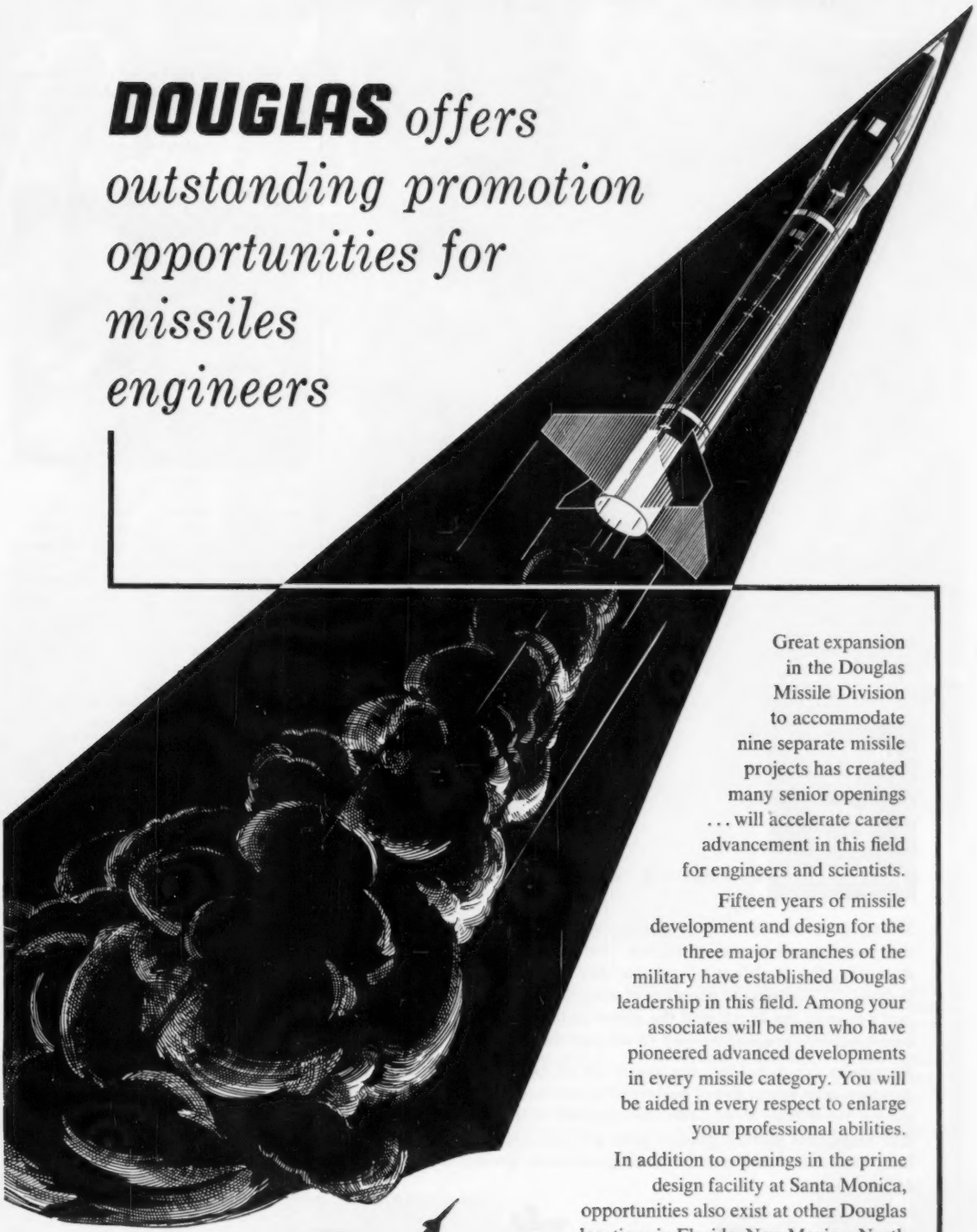

Great expansion in the Douglas Missile Division to accommodate nine separate missile projects has created many senior openings . . . will accelerate career advancement in this field for engineers and scientists.

Fifteen years of missile development and design for the three major branches of the military have established Douglas leadership in this field. Among your associates will be men who have pioneered advanced developments in every missile category. You will be aided in every respect to enlarge your professional abilities.

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For a personal interview, contact E. C. Kaliher, Missiles Engineering Personnel Manager, Box 620Q
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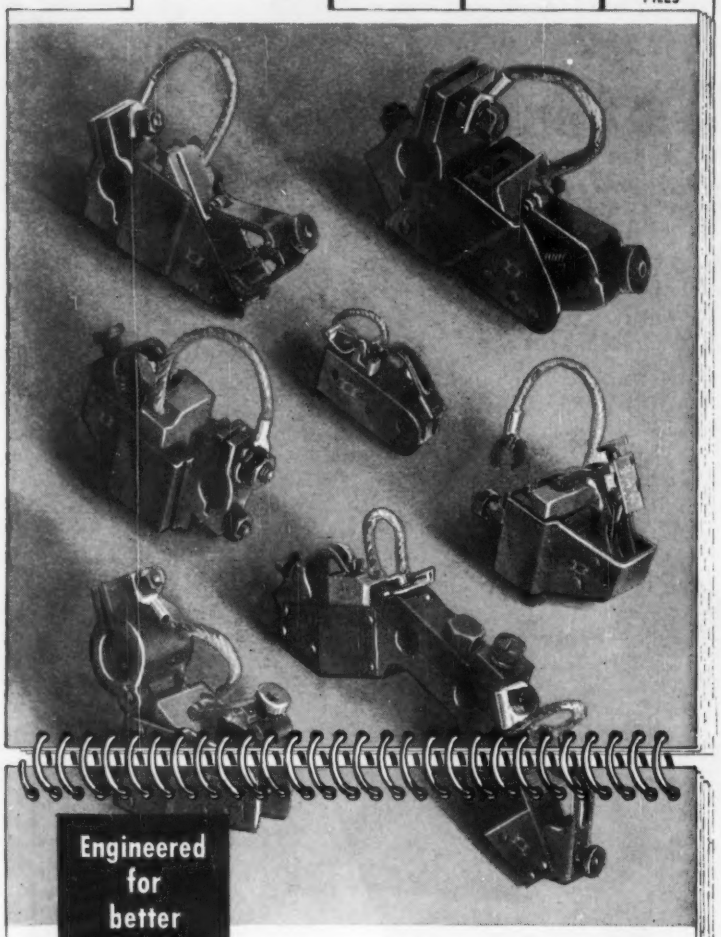
BRUSH-HOLDERS | CONTACTS | CURRENT COLLECTORS | VOLTAGE REGULATOR PILES



Engineered for better brush performance ...with MORGANITE

Selecting the right brush grade is no more important than the selection of a well-designed, well-made brush-holder. Actually, the problem of satisfactory brush operation is largely the mechanical problem of maintaining intimate contact between the brush and the commutator. *And Morganite brush-holders are engineered to do just that.*

Morganite brush-holders are the result of exhaustive investigation and tests. Every technical superiority discovered during these tests have been incorporated into their design. Our engineers will be glad to give you the benefit of their long experience in this field. Simply write us, giving all the facts you can.

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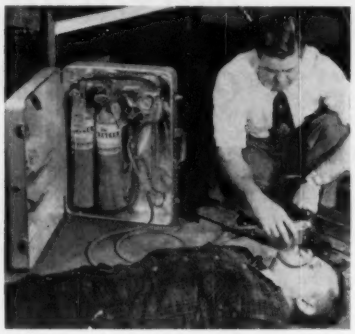
## New Products

(*Continued from page 74A*)

or vomitus from the throat. As an inhalator, it supplies oxygen to be absorbed by spontaneous respiration. The resuscitator is employed with standard masks or, through an adapter, with any size tube or



catheter for intubation or tracheotomy. The head can be readily removed and sterilized in boiling water. The compactly built breathing mechanism, small enough to fit in the palm of the hand, can be used 200 feet away from the oxygen supply. This makes it possible to reach and revive accident victims in tunnels, tanks, and other hard-to-get-to places. The carrying case is made of a tough aluminum alloy and designed to stand up under hard service. It is impervious to moisture, grease, and stains. The case accommodates two standard "D" oxygen cylinders. Its weight without cylinders is 26 pounds.

**Item 67 on the card.**

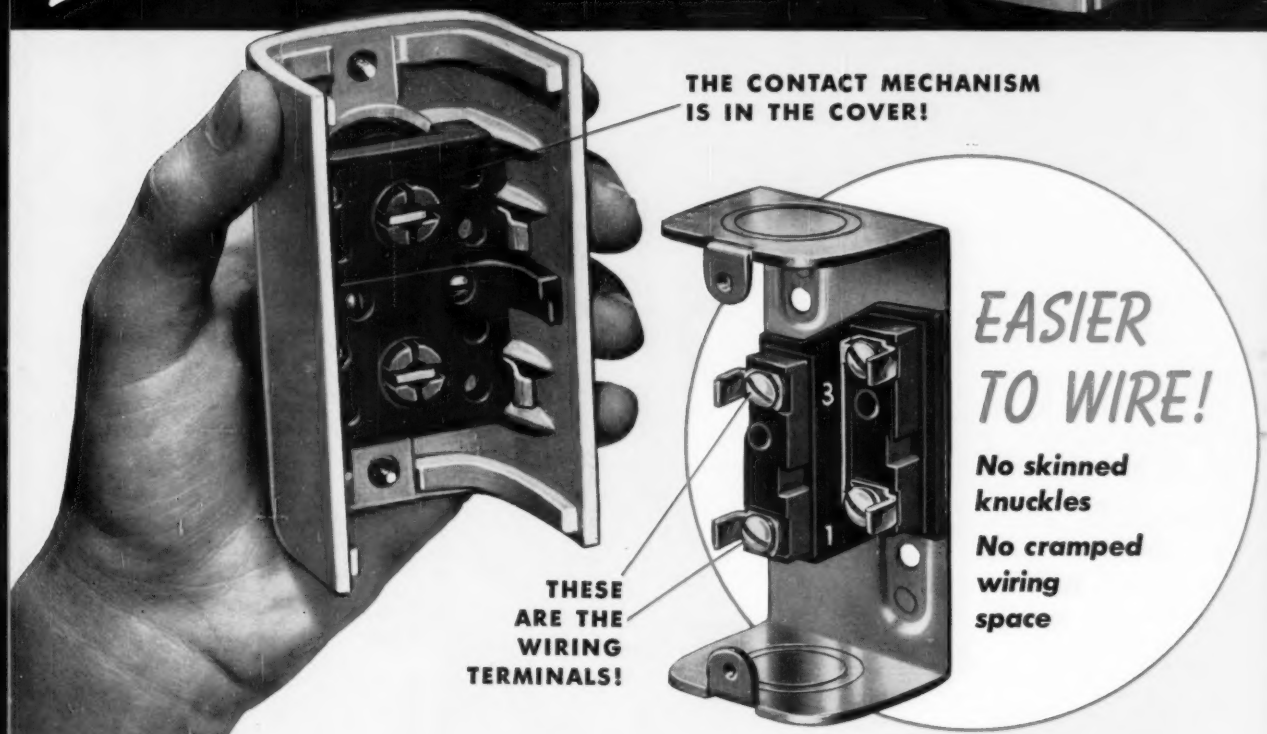
**Miniature TV Camera.** A cigar-shaped television camera, called the "Peepsqueek" believed to be the world's smallest, now opens a completely new era for industrial, scientific, and medical television viewing. The new camera is less than six inches long, measuring only $1^{7}/_{8}$ inches in diameter. Its miniature size permits thorough inside inspection of previously inaccessible areas. Equipped with two sets of spring-loaded guide rollers, it travels through pipes, tubing, walls, etc., that have an inner diameter of $2^{1}/_{8}$ inches or more, and a bending radius of a mere 14 inches. This remote-controlled unit contains a miniresistron and a number of subminiature tubes that serve as amplifying elements. A conical mirror accessory may be mounted three-quarters of an inch ahead of the lens combination to reflect the image of the inside walls. The image received can be magnified up to 20 times since the focal length of the lens system is only one-half inch. The camera is manufactured in West Germany by Grundig Radio-Werke GmbH and is marketed in the United States under the Grundig-Majestic trademark exclusively by Majestic International Corporation.

**Item 68 on the card.**

(*Continued on page 79A*)

# Brand New Idea

## in STANDARD-DUTY STATIONS




## EASIER TO WIRE!

***No skinned knuckles***

***No cramped wiring space***

Here's an entirely new idea in push button stations—a wrap-around cover—with the contact mechanism part of the cover. Removing the cover exposes the terminals for instant and easy wiring. Strong, spring type, silver plated contacts connect the push button assembly in the cover with the terminals in the base.

Matching ribs in the cover and notches in the terminal blocks assure that the wiring connections are always correctly made. A bakelite shield protects the contact mechanism and prevents careless wiring from interfering with the contact operation. Concentric knockouts are provided in both top and bottom of the heavy metal base.

You will want to know about this new standard-duty station because—it is good looking—it takes less time to install—it was designed for the convenience of the installation engineer.

Let us show you a sample of this "brand new idea" in standard-duty stations!

A-B Quality

**ALLEN-BRADLEY**

QUALITY

**MOTOR CONTROL**

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.
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Bulletin 800 standard-duty push button stations can be supplied with one, two, or three buttons, or as a selector switch. Also available with pilot light. Furnished only in NEMA Type 1 enclosures.

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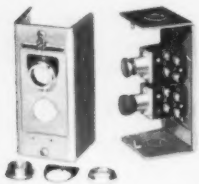
# *Also... NEW* HEAVY-DUTY PUSH BUTTONS

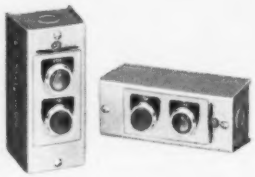
BULLETIN 800

## NEW FLEXIBILITY!



You can assemble any special heavy-duty station from a small stock of standard push button, selector switch, and pilot light components. There is no need to wait for long delivery of your special stations.

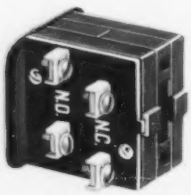
Stations can be arranged for either vertical or horizontal mounting. Name plates can be rotated to any position, replaced with any standard marking, or removed entirely.



## NEW ENCLOSURES!

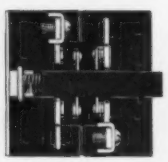
Each button, selector switch, or pilot light is a self-contained unit which can be mounted in attractive new enclosures. Standard enclosures accommodate up to eight units, but enclosures can be furnished for larger numbers.

## NEW CONTACT BLOCK!



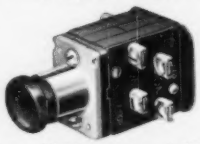

Above: View of contact block, showing terminals for normally open and normally closed contacts. Right: Contact block, with cover removed, showing stationary silver alloy contacts and pushrod carrying the moving contacts.

Bulletin 800 heavy-duty push buttons have the same molded contact blocks that have proved so dependable in Bulletin 800T oiltight push buttons, although they are not themselves oiltight. And all of them are equipped with double break, silver alloy contacts.

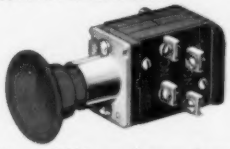


## NEW OPERATORS!

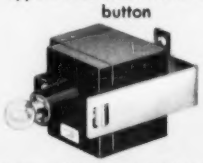
Operators, which mount on the contact block, are available in many types, and push buttons come in various colors.



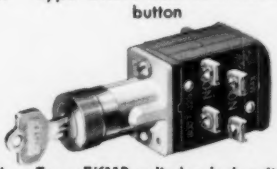
Type AK2B flush head START button



Type DK6A mushroom head button



Type PK16 pilot light with transformer



Type EK11B cylinder lock unit

9-56-MR

A-B Quality

**ALLEN-BRADLEY**

QUALITY

MOTOR CONTROL

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis. In Canada—Allen-Bradley Canada Ltd., Galt, Ontario

(*Continued from page 76A*)

**Miniature Flexible Coupling.** A miniature flexible coupling has been especially developed for subfractional horsepower motors and other small units. Typical subfractional motor applications include coding devices, radar equipment, film type and tape recorders, X-ray machines, actuators, laboratory test equipment, and aircraft components. Others are solenoid units in dispensing machines, coin operated devices, and similar equipment. Rated at 1/20 hp at 1,750 rpm, the full range is from 0.003 hp to 100 rpm to 0.103 at 3,600 rpm. Dimensions are 5/8 inch O.D. by 3/4 inch over-all length. Bore sizes are 1/8 inch, 3/16 inch, 1/4 inch, and 5/8 inch. Bodies are standard in die cast aluminum but can also be furnished in brass. Spiders are one-piece spider type and are made from a resilient Buna-N compound. This compound is equal to rubber in elasticity, strength, resilience, and resistance to abrasion, yet is far superior in resistance to oils, chemicals, heat, ozone, and aging. The miniature flexible coupling, by Lovejoy Flexible Coupling Company, never requires lubrication and is otherwise maintenance-free for the normal life of the equipment. There is no wear on the metal jaws, because the load is transmitted by cushion compression.

**Item 70 on the card.**

**Mercury Lamp.** A 1,000-watt mercury lamp with an interior phosphor reflector which directs two thirds of the light downward has been announced by the General Electric Company (GE) lamp division. The lamp, designated *GE H1000 RC 15*, has phosphor coating on the base half so that two thirds of its light output is directed down and one third up. Thus, less light is controlled by the external lighting fixture. The new lamp is $15^{1}/_{16}$ inches long, has a mogul base, and is rated at 53,000 lumens. It will be used in medium and high mounting in industrial installations. A companion lamp, the *H1000 RC 12*, will also be made. Its operating voltage is 135 volts, whereas the *H1000 RC 15* operates at 265 volts. Both lamps will utilize the same outer bulb and will have similar light distribution.

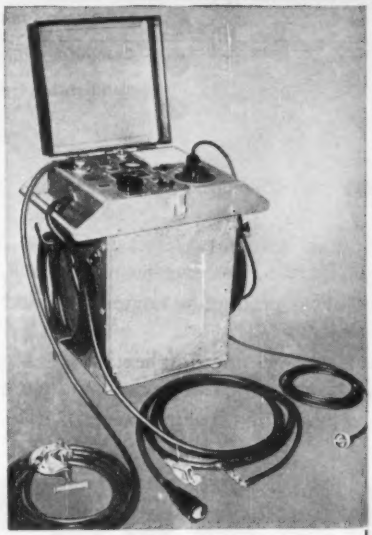
**Item 71 on the card.**

**Electric Heating "Peaks" and "Valleys" Cut.** Two line voltage thermostats have been developed to take the uncomfortable hot "peaks" and cold "valleys" out of electric heating. One does it by fast cycling (up to 20 times per hour), the other by cycling only three to six times an hour. The former, designated the *T-40*, is ideal for low-mass, quick heating–quick cooling units, say engineers of Minneapolis-Honeywell Regulator Company who developed both new instruments. The latter, called the *T-41*, is better suited for large-mass, slow heating–slow cooling systems such as are used in ceiling and floor cable heating applications. Both instruments operate without supplemental relays or transformers.

**Item 72 on the card.**

(*Continued on page 92A*)


# BIDDLE *Instrument News*



## BIDDLE IMPULSE CABLE FAULT LOCATING TRANSMITTER

### Model 5, 5 KV, 16 MUF

Those companies operating an appreciable amount of 600 volt cable should be particularly interested in this recently developed transmitter. Those having cable in the 2500 volt delta and 4000 volt wye insulation class will also find this transmitter well suited to their needs for proof testing and locating faults on important circuits. Similar applications include the proof testing and location of faults in drag cables such as used with electric shovels in strip mines. Still other applications include extensive lighting circuits such as used at airports and in highway lighting.

**BIDDLE IMPULSE CABLE FAULT LOCATOR EQUIPMENT NOW INCLUDES:**

Model 3, 25 KV, 1.65 MUF
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**—for measuring d-c current at voltages up to 40 kv when applied to the insulation of such equipment as generators, transformers, bushings and cable.**

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James G. Biddle Co.
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4-8 years experience in airframe dynamics in: compressible subsonic and supersonic flutter analysis on straight and swept wing vehicles, flutter model techniques, vibration testing techniques. Desirable: experience in landing and gust response calculations, carrier suitability analysis, ejection seat trajectory calculations. Advanced degree required.

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*Flutter Analysis*
3-5 years general flutter analysis experience, including subsonic compressible and supersonic airforces for both straight and swept wing vehicles. Advanced education desired in mathematics, physics, applied mechanics, aeronautical or mechanical engineering.

**SENIOR ENGINEER**
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*Model and Vibration Testing*
3-5 years experience in flutter model building and test, in addition to general flutter analysis experience. Advanced degree desirable.

**GROUP ENGINEER**
*Propulsion*
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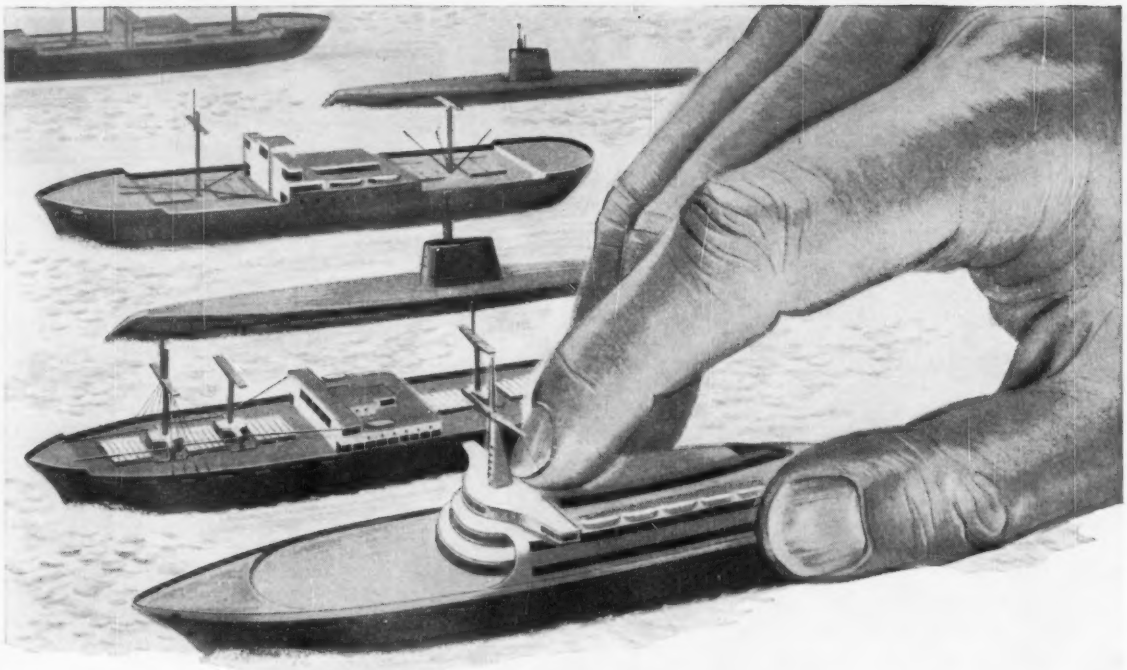
# ENGINEERS...



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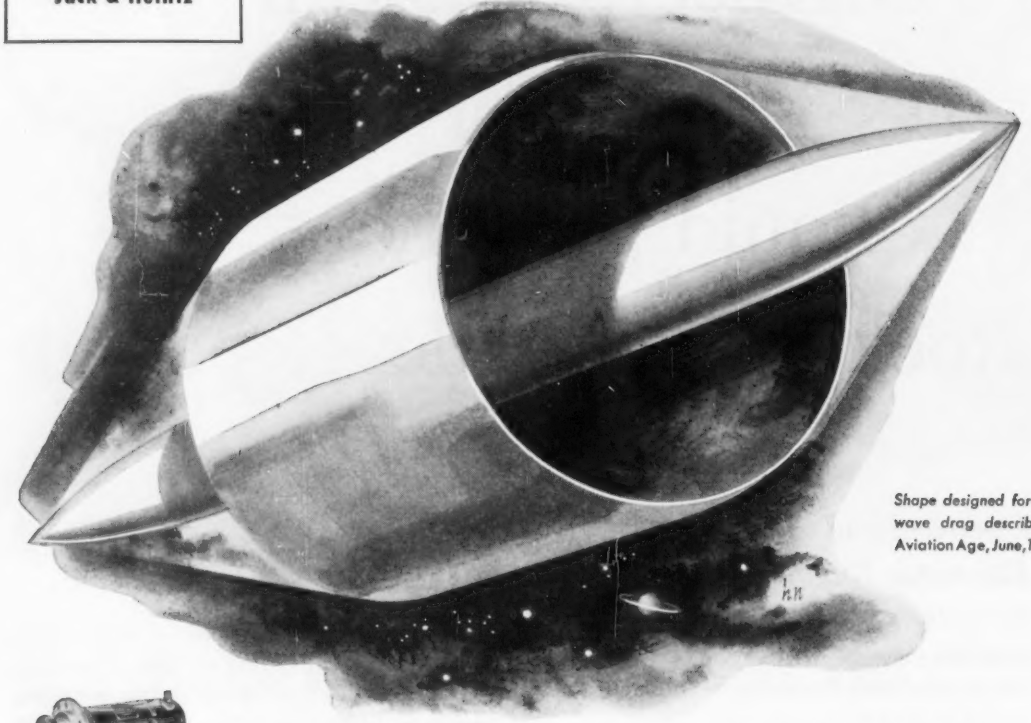
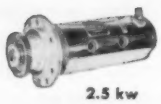
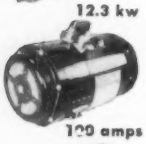


*Shape designed for zero wave drag described in* Aviation Age, *June, 1956.*

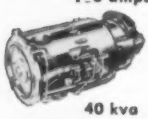


2.5 kw

12.3 kw



100 amps



40 kva

20 kva

17 kva

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| Nominal Rating | 2.5 kw | 12.3 kw | 100 amps | 40 kva | 20 kva | 17 kva |
| Volts | d-c 3 outputs | a-c, d-c 3 outputs | 30 | 120/208 | 120/208 | 120/208 |
| Speed (rpm) | 12,000 | 12,000 | 8,000 | 6,000 | 8,000 | 12,000 |
| Phase (cps) | — | — | — | 3 | 3 | 3 |
| Frequency (cps) | — | 1,600 400 | — | 400 | 400 | 400 |
| Power Factor (min) | — | — | — | .75 | .75 | .75 |
| Weight (lb) | 30 | 70 | 36¼ | 165* | 100* | 50 |
| Length (in.) | 12.71 | 14.3 | 10.57 | 27.25* | 26.0* | 12.85 |
| Diameter (in.) | 4.5 | 7.75 | 6.5 | 13.0* | 9.5* | 7.5 |

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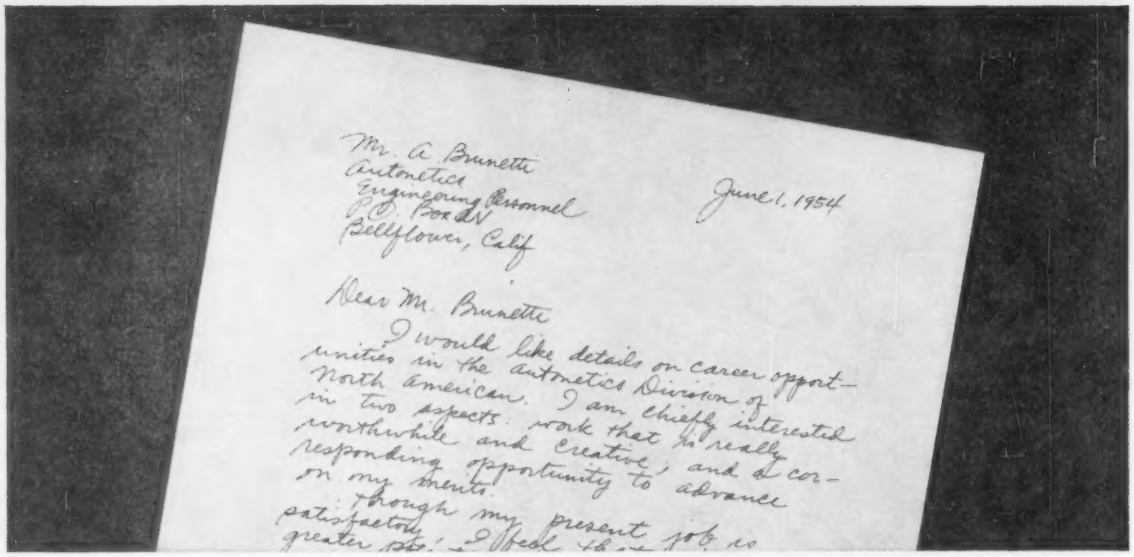
Mr. A Brunetti
Autonetics
Engineering Personnel
P.O. Box AN
Bellflower, Calif
June 1, 1954
Dear Mr. Brunetti
I would like details on career opportunities in the Autonetics Division of North American. I am chiefly interested in two aspects: work that is really worthwhile and creative, and a corresponding opportunity to advance on my merits.
Though my present job is satisfactory,

# This letter moved a man ahead 5 years

Two years ago a man took 10 minutes to write this letter. Today he enjoys the responsibility and professional standing in the AUTONETICS Division of North American that might have taken 7 to 10 years to achieve in other fields.

**THE FIELD AT AUTONETICS—A FIELD OF OPPORTUNITY**

Now under way at AUTONETICS are nearly 100 projects, comprising some of the most advanced and progressive work being done today in the fields of Electronics, Electro-Mechanics, Control Engineering and Data Processing.

You will work on automatic control systems of many kinds, for manned and unmanned vehicles. Every state of the art is represented, from preliminary conception right through flight testing. Facilities are the finest obtainable. Your colleagues will be men of ability and imagination, of the highest professional standing.

The long-range potential in this field is truly limitless. The techniques being developed at AUTONETICS today will have the widest application in the industrial methods of tomorrow.

You owe it to yourself to consider how far you can advance by entering this exceptionally promising field right now. Here are the opportunities:

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Write your letter today. Decide now to get the facts, so you can make the most of your potential. Just put your address and brief qualifications on paper—handwritten will be fine. Reply will be prompt, factual, confidential.

**Write: Mr. A. Brunetti, Autonetics Engineering Personnel, Dept. 991-11 EE, P. O. Box AN, Bellflower, California**

**Autonetics**
A DIVISION OF NORTH AMERICAN AVIATION, INC.

AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

# An Engineer and his Family
## Enjoy Life in Upstate New York

*where he is associated with the*

**Electronic Tube Division of**
**WESTINGHOUSE ELECTRIC CORP.**
**Elmira, N. Y.**

Engineers change jobs for many reasons. Here is a typical example of the reasons why many engineers have selected the Westinghouse Electronic Tube Division in Elmira, N. Y. as the place to advance their engineering careers, and why they like the Elmira area as a place for pleasant family living:

"It took me several years to realize that selecting the right job in the right location is really a "family affair." Unless the wife and kids are happy, too, there's not much sense in sticking with a job...no matter how interesting the work is.

"About a year ago, we decided that "big city" life was not doing our family any good. Marge had made a few good friends, but didn't feel she had grown "roots." Our two youngsters, Billy and Linda, were nervous and high-strung.. with no good place to play. My salary was pretty fair, but the high cost of city living ate it up quickly.

"That's when I started looking around for an opportunity that would enable us to live in more congenial surroundings. We checked into several offerings, but none seemed to suit us.

"Then I saw an ad for openings in the Westinghouse Electronic Tube Division in Elmira, N. Y. It sounded like the kind of work I wanted, so I phoned Bob Jarrett, the employment supervisor, and arranged for an interview. That was our lucky day!

"After traveling to Elmira and talking with Mr. Jarrett, I found that my E.E. degree and previous experience qualified me for a position in the Camera Tube Design Section. With a little instruction, I could qualify for several other jobs, too.

"Mr. Jarrett explained about the Westinghouse pension and insurance plan. It was the kind of protection I needed for my family.

"He also told me there would be a 3% general increase in salary each Fall for the next three years, quarterly cost of living adjustments, and periodic review of my work to determine merit increases. Because the Electronic Tube Division is new and expanding rapidly, the chances for promotion are unusually good.

"I liked the looks of the clean little city, the attractive residential areas, and rolling wooded hills all around. About a mile from the plant, I spotted a super golf course!

"When I asked Bob Jarrett about outdoor activities, he said there was wonderful fishing, boating and swimming in the Finger Lakes, about 25 to 30 minutes' drive. (Lots of Westinghouse folks have summer cottages there and commute to work)

"Well, to make a long story short, I received an offer through the mail in a few days that seemed mighty attractive. When I took Marge and the kids to see what Elmira was like, they fell in love with the place!

"My work at Westinghouse this past year has been richly rewarding. Plenty of design problems to challenge my engineering training and experience. Working together as a team, my colleagues and I are making significant contributions in the field. I'm finally advancing my engineering career.

"As for Marge and the kids, let her tell about that...

"Well, like most engineer's wives, I'd be willing to live wherever Jim's work took him. But when Billy and Linda came along, it was different. I wanted them to grow up in a community where there were good schools, churches, and clean wholesome surroundings.

"When Jim accepted a position with the Westinghouse Electronic Tube Division and we moved to Elmira, I knew we had found exactly what we wanted.

"Everyone seemed so friendly and anxious to help us get acquainted. The folks at Westinghouse helped us locate a darling little home...only 6 minutes' drive from doorstep to plant.

"I was invited to join the Newcomer's Club...so I got acquainted quickly. And we were soon made to feel at home in one of the many churches.

"Elmira is large enough to have all kinds of organizations and cultural interests.. community concerts, Little Theatre, camera club, bird-watching, bowling, sailing, hiking and bridge. Yet, it's small enough to be close to fields and forests.

"Jim seems so much more relaxed now. He's working hard at Westinghouse because he loves it, but here he can enjoy the things he was missing in the "big city."

"I've found many fine places to shop... modern department stores, super-markets, and everything! Our living costs are down, too. Jim grew a grand vegetable garden in our back yard...and I'm getting interested in raising flowers.

"Both the children have grown taller and huskier since we left the "big city," and they've lost their high-strung temperament.

"This is real family living, and we are all growing "roots" in the community, thanks to Jim's decision to work at Westinghouse."

---

**If you are interested in advancing your career in the electronics field, we invite you to submit information which may lead to an interview. At present we have opportunities for engineers in Tube Design and Development for Microwave Tubes, Receiving Tubes, Pickup Devices, Power Tubes, Cathode Ray Tubes; Application Engineering, Electrical Equipment Design, Manufacturing Engineering, and Glass Engineering.**

**In submitting information concerning your background, phone collect to Westinghouse Electronic Tube Division, Elmira 9-3611 and ask for Robert M. Jarrett. (After 5 p.m. or weekends, phone collect Elmira 9-2360.) If you prefer, write a letter to Mr. Jarrett, Dept. L-22, giving basic information, and ask any questions you wish.**

# ENGINEERS

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2. **Distribution Planning (E.E.)**
3. **System Planning and Protection (E.E.)**
4. **Distribution Field Engineering (E.E.)**
5. **Transmission Field Engineering (E.E.)**
6. **Test Engineer** POWER PLANT **(M.E. or Ch.E.)**

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To apply for one of the above positions, please fill in the following:

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DATE OF BIRTH_____

EDUCATION — GIVE COMPLETE DETAILS — USE SEPARATE SHEET IF NECESSARY

| LAST SCHOOL ATTENDED | NAME-LOCATION OF SCHOOL | ENCIRCLE LAST YEAR COMPLETED | MAJOR COURSE AND OPTION | DEGREE | LAST YEAR ATTENDED |
|---|---|---|---|---|---|
| COLLEGE OR UNIVERSITY | | 1 2 3 4 | | | 19 |
| OTHER | | 1 2 3 4 | | | 19 |

EMPLOYMENT RECORD — POSITIONS HELD INCLUDING PRESENT
USE SEPARATE SHEET IF NECESSARY

| FROM | TO | NAME OF EMPLOYER | LOCATION | NATURE OF POSITION | SALARY | REASON FOR LEAVING |
|---|---|---|---|---|---|---|
| MONTH 19 | MONTH 19 | | | | | |
| MONTH 19 | MONTH 19 | | | | | |

POSITION PREFERRED_____

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SPRINGFIELD, ILLINOIS

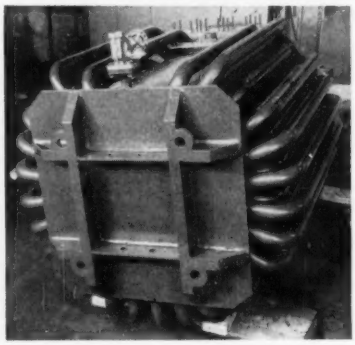
This information will be held in confidence
Present Employer will not be contacted without your permission


(*Continued from page 79A*)

## TRADE LITERATURE

**Book and Film.** Despite the trend to direct-current drives in recent years, there are still those who consider direct-current outmoded, and who ask, "Why d-c?" To answer this query in understandable, layman's terms, the direct-current motor and generator department of General Electric Company, has published a nonpromotional 32-page booklet entitled "Why D-C?" Copies of this publication may be had free of charge by writing the General Electric Company, Schenectady, N. Y., requesting publication *GED-2868-S*. Another new item presented by General Electric is a 30-minute sound and color motion picture "Goodbye Steve" to be shown to manufacturing and engineering audiences. The film is the latest in a series of productions in General Electric's "More Power to America" program. It is part of a kit which includes a 52-page manual entitled "The Power to Produce," showing the unusual equipment investment opportunities offered industrial management by power distribution. The kit can be obtained through local electric utility companies or through the Apparatus Sales Division, Section *6-210*, General Electric Company, Schenectady 5, N. Y.

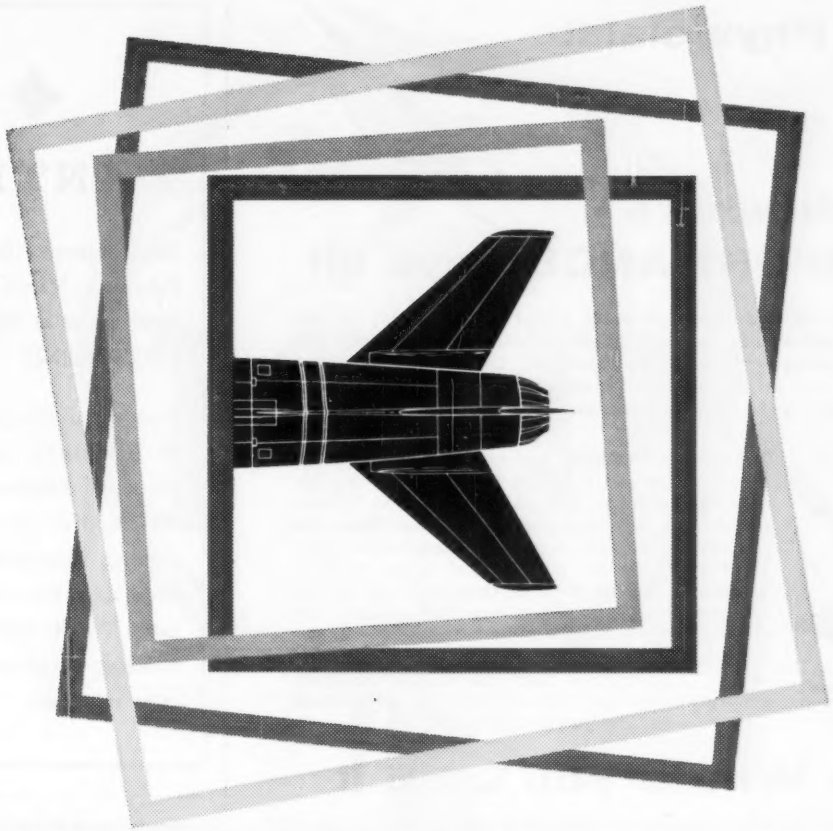
**Transformer Instruction Booklet.** The Moloney Electric Company has issued a transformer instruction booklet which should be of value to all those interested in distribution transformer maintenance



and operation. The eight-page well-illustrated bulletin covers installation, operation, component parts, maintenance, and inspection of distribution type transformers in ratings of 250 to 500 Kva, 3-phase. This booklet, form *DL-1*, may be obtained by request on company letterhead to Moloney Electric Company, Advertising Department, 5390 Bircher Blvd., St. Louis, Mo.

**Electronic Timers.** An 8-page brochure with current information and specifications describing the standard line of electronic timers manufactured by G. C. Wilson and Company, 1915-8th Ave., Huntington, W. Va., is now available. Included in this line are delay, repeat cycle, and interval timers.

(*Continued on page 96A*)



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**ALSO NEEDED:** Aerodynamicists, Systems Engineers, Instrumentation Engineers, Aero-Thermodynamicists, Aeroelastic Engineers, Cycle Analysis Engineers

**Contact Les Stevenson, Engineering Personnel Office, Dept. 56-11EE**
**North American Aviation, Inc., Los Angeles 45, California**

**North American Aviation, Inc. is doing research and development on the X-15, a manned aircraft for investigation of speeds and temperatures at very high altitudes.**

Los Angeles Division

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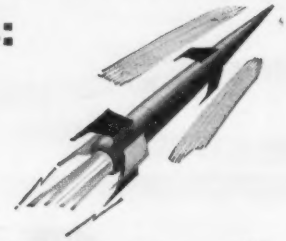
# Physicists:



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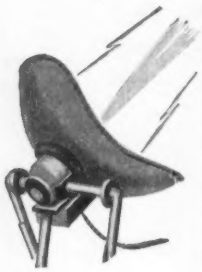

Melpar believes that the engineer deserves an organization and facilities that can enhance his creative abilities. For this reason our laboratories were designed and built to specifications prepared by Melpar engineers. A wealth of equipment is available. Our project group system enables the engineer to participate in all phases of development problems and thus quickly acquire greater technical and administrative know-how, essential to eventual managerial responsibility. The system also enables us to more accurately evaluate the individual's contribution and more rapidly justify promotions.

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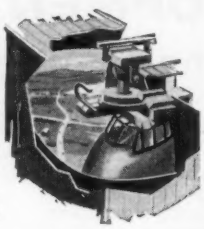
Living—for the whole family—is immensely rich in the two locales where Melpar's R & D activities are centered. Our 265,000 sq. ft. main laboratory near Washington, D. C., enables you to live in an area enjoying incomparable cultural and recreational advantages. The climate allows outdoor recreation 215 days of the year. Fine homes and apartments are available in all price ranges. Our Watertown and Boston, Mass. laboratories offer the unique advantages of cosmopolitan Boston with its theatres, concerts, art galleries, museums, universities and schools which are second to none. Nearby are seaside and mountain resorts offering a variety of winter and summer sports.



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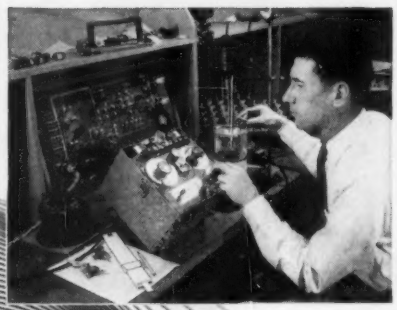

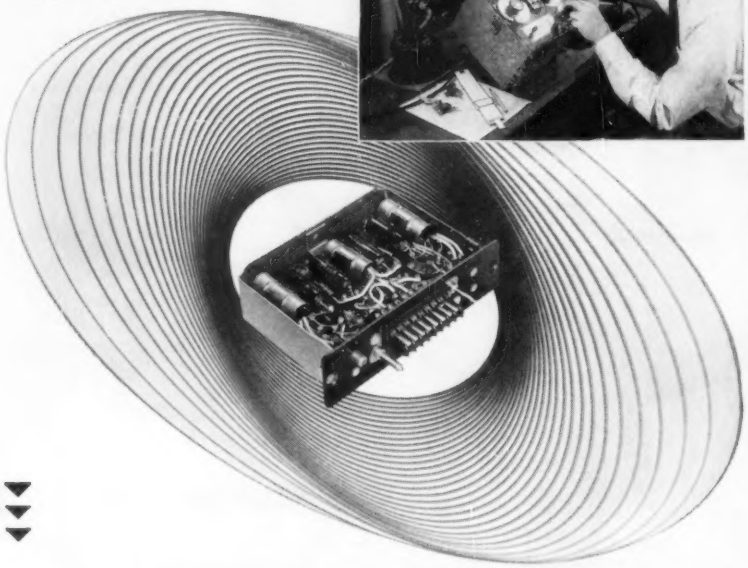

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## Trade Literature

(*Continued from page 92A*)

**Short Arc Lamps.** A new manual explains their application in searchlight, projection, and optical service. The booklet, according to W. B. Gero describes the various types of short-arc lamps, mercury, mercury-xenon, and lists their applications. The manual also contains diagrams of the various types of lamps and graphs of typical arc brightness curves. Complete technical data and operating instructions for short-arc lamps is included in the write-up. The arc brightness of these light sources exceeds that of any other existing lamp, ranging up to 400 candlepower per square millimeter. They are designed for natural draft cooling and require no forced ventilation. The booklet, "Westinghouse Short-Arc Lamps" (*CE-556*), may be obtained by writing to the Westinghouse Lamp Division, Bloomfield, N. J.

**Plastics.** A glossary of plastics terms has been published and is available on request to The Richardson Company, 2769 Lake Street, Melrose Park, Ill., manufacturer of molded and laminated plastics. The glossary lists about 85 definitions, including terms such as bonding strength, center expansion, delamination, flexural strength, postforming, and thermoplastic.

**Insulation Connectors.** A 4-page handbook supplement featuring a new series of simple, rugged Alden "IMI" (integral molded insulation) connectors is now available from Alden Products Company, Brockton, Mass. These high voltage and multiwire connectors provide perfect strain relief on all leads, positive seal against moisture, prevention of arc-over, and corona suppression. The Alden "IMI" technique provides, perhaps, the simplest construction possible in connectors to date. The entire connector assembly, contacts and leads with any supplementary circuitry or shielding means desirable, are molded with one shot into a finished connector. By choosing connector insulation of the same type as the wire insulation a homogeneous bond is made between wire and connector insulation. This can give the designer more compact connector designs for an infinite variety of contact layouts and connector functions, and makes possible completely molded unit cables.

**Design and Use Data on Ceramic Magnets.** A review of the several characteristics of this relatively new permanent magnet material that are of special interest to product designers is given in *Applied Magnetics* vol. 4, no. 3, a publication of the Indiana Steel Products Company, Valparaiso, Ind. How the special properties of *Indox I* have been used to advantage in such varying fields as electronics and toys and novelties also is discussed. Copies of the publication will be sent to those who request it by writing the Indiana Steel Products Company, Department AM, Valparaiso, Ind.

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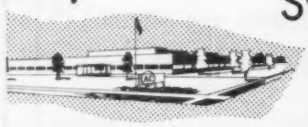
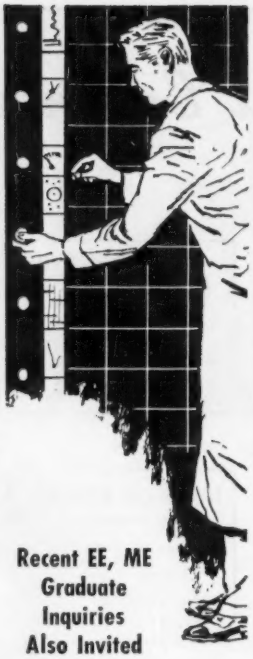
# Servo Engineers

## ELECTRICAL MECHANICAL

Inertial Guidance System Program





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**When answering an advertisement, send all replies to box number specified, c/o ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 36, N. Y., unless other address is given.**

### Positions Open

ENGINEER with graduate degree in electrical engineering for research and development work in small instrument manufacturing company in Philadelphia specializing in electro-mechanical audio frequency responsive devices and dielectric measurements. Box 440.

PROFESSOR OF ELECTRICAL ENGINEERING—to teach and do research in the field of communications. Should have Ph.D. teaching and research experience. $9,400–12,000. Write Box 468.

GRADUATE ASSISTANTSHIPS—are available at University in the south-east for September 1957. Assistants may obtain a M.S. Degree in Electrical Engineering in twelve months. Tuition free. Write Box 469.

SALES REPRESENTATIVES WANTED—to sell special automation control panels, instrumentation, test panels, explosion proof controls to both O.E.M., industrial and users. Well-rated, well-established firm now expanding from Midwest. Many key East Coast and other territories open to qualified men. GEMCO ELECTRIC COMPANY, 25681 West Eight Mile Road, Detroit 19, Michigan.

PERMANENT STAFF POSITIONS IN ELECTRONICS open in Electrical Engineering Fall, 1956 at the South Dakota School of Mines and Technology, Rapid City, South Dakota. Ph.D. preferred but will consider M.S. degree. Expanding department to include graduate school. Ten month appointment, rank and salary commensurate with qualifications. Located in the Black Hills region of South Dakota. Write Head, Department of Electrical Engineering.

ELECTRONICS ENGINEERS. Significant and challenging programs in the fields of radar-aeronautical systems and electronics. The programs are categorized in a broad sense as follows: RADAR-AERONAUTICAL SYSTEMS—All-weather flight systems, radar control systems for airplanes and missiles, flight control computers, and specialized radar research. ELECTRONICS AND AUTOMATIC COMPUTERS—Communications and data processing systems electronic computer techniques, flight simulators, with detailed electronic circuitry involved in these applications. Cornell Aeronatutical Laboratory, Inc., 4467 Genessee Street, Buffalo 21, New York.

OPPORTUNITIES IN TESTING FIELD FOR EXPERIENCED ELECTRICAL ENGINEERS AND E.E. GRADUATES with small, well-established, employee-owned company, offering usual benefits plus potential profit-sharing and stock ownership . . . Interesting and important assignments covering broad range of testing, engineering analyses and inspection in electrical, electromechanical and environmental fields on all kinds of electrical materials, instruments, apparatus and equipment. High order of personal responsibility in work and client relationships. Also openings for engineers and specialists experienced in watthour meter and instrument testing and calibration, component evaluation, electrical appliances, air-conditioners, high-voltage cable . . . Openings for engineers and specialists familiar with in-plant cable testing and inspection, instrument and test apparatus checking and calibration, in-plant audits of inspection, quality control, and specification compliance procedures. Please send resume of education and experience, stating age and salary requirements to Gordon Thompson, Chief Engineer, Electrical Testing Laboratories, Inc., 2 East End Avenue, New York 21, New York, Telephone, BUtterfield 8-2600.

ELECTRICAL ENGINEER OR ENGINEERING PHYSICIST—recent graduate, major in illumination engineering and optics for training as assistant in photometric department of small but well established, employee-owned independent laboratory. Many employee benefits including non-contributory retirement and profit-sharing. Stock purchase opportunity. Work in fields of photometric, radiometric, colorimetric and spectrophotometric measurements, determinations and analyses on all types of illuminants, materials and equipment. Considerable work with industry and technical societies on standards, specifications, testing procedures and criteria. Interesting, important and wide ranging assignments. If qualified please send resume of education and experience, stating age and salary requirements, to E. H. Salter, Electrical Testing Laboratories, Inc., 2 East End Avenue, New York 21, New York, Telephone, BUtterfield 8-2600.

ELECTRICAL ENGINEER OR ENGINEERING PHYSICIST—recent graduate, major in illumination engineering and optics for training as assistant in photometric department of small but well established, employee-owned independent laboratory. Many employee benefits including non-contributory retirement and profit-sharing. Stock purchase opportunity. Work in fields of photometric, radiometric, colorimetric and spectrophotometric measurements, determinations and analyses on all types of illuminants, materials and equipment. Considerable work with industry and technical societies on standards, specifications, testing procedures and criteria. Interesting, important and wide ranging assignments. If qualified please send resume of education and experience, stating age and salary requirements to Gordon Thompson, Chief Engineer, Electrical Testing Laboratories, Inc., 2 East End Avenue, New York 21, New York, Telephone, BUtterfield 8-2600.

ENGINEERS—Openings in transformer design engineering and related apparatus, research and development in field of high voltage phenomena, studies of electrical properties of insulations, stress analysis and heat transfer. BS or MS degree in electrical or mechanical engineering. Experience up to five years useful, but not essential. Write Personnel Section, General Electric Company, Transformer Division, Pittsfield, Mass.

ATTENTION ELECTRICAL ENGINEERS—who like outdoor sports and hobbies–Live in beautiful Minneapolis, City of Lakes; conveniently enjoy sailing, swimming, skating, skiing, fishing, photography, hunting. . . . .; and work for progressive manufacturer of large synchronous and induction motors, control and switchgear. Numerous positions open in Headquarters Sales and Service Departments with advancement opportunities either within department or into outside sales force. Excellent future for aggressive extrovert type men who prefer stimulating work and surroundings. Also immediate openings in outside sales offices and in Engineering Department for qualified men. Box 478.

ENGINEER—for electric motor manufacturer. Experienced, capable in design of standard and special motors. Box 479.

APPLICATION ENGINEER—INDUSTRIAL CONTROL—Nationally known manufacturer of industrial power control tubes offers excellent opportunity for graduate Electrical Engineer with some engineering experience and an interest in industrial electronics and automatic control. Moderate travel requirements. Box 482.

DESIGN ENGINEERS-ELECTRICAL CABLE—In New Jersey—positions open with large insulated wire and cable manufacturer for engineers up to 35 years old with 5 to 7 years experience. Experience in design of rubber and paper insulated cables, high voltage cables, etc. Permanent positions. Salary commensurate with experience. Write stating age, education, experience and salary desired. Box 483.

INSTRUCTOR IN ELECTRICAL ENGINEERING—preferably one with M.Sc degree and some industrial experience, to teach general electrical engineering subjects. Will consider one with only a B.Sc.E.E. degree if he is willing to work for M.Sc. degree. May start teaching immediately. Write Chairman, Department of Electrical Engineering, University of Nebraska, Lincoln 8, Nebraska.

CHIEF ENGINEER—ELECTROLYTIC CAPACITORS. Must be capable of designing complete line. Should be familiar with manufacturing techniques and controls. Will report to Plant Manager. Location—South-central. Salary open. Please reply in confidence to Box 491.

ELECTRICAL ENGINEER—Electrical Engineer interested in electrical design of power plants or industrial plants. Experience not required. Excellent opportunity with consulting engineering firm in Middle West. Liberal benefit plans and good working conditions. Send resume of education and experience with statement of salary requirements to Box 492.

ELECTRIC UTILITY EXECUTIVE—A large engineering and construction firm in Eastern Pennsylvania is looking for a man who has been, or is now, engaged by an electric utility company in the capacity of senior or junior executive. His primary duty will be that of contacting executives and officials in the Utility field to promote relations and solicit inquiries for engineering and construction services in connection with power plant expansion programs. Applicants should be free to travel and have high order of personal responsibility in work and client relationships. Salary open. Write outlining personal history and work experience. Please include telephone number. Box 493.

ELECTRICAL ENGINEER with M.S. or B.S. and up to 5 years experience. Major oil company. To work as Staff Engineer in Production Department. Includes various Electrical Engineering Studies especially corrosion and oil field electrification problems. Replies confidential. Please submit resume of background and experience to The California Company, 800 California Building, New Orleans, Louisiana.

INSTRUCTOR AND PROFESSORIAL RANK TEACHERS needed in electrical engineering starting February 1, 1957. Extensive graduate program and research activities. Location—Pennsylvania. Box 496.

### Positions Wanted

ASSISTANT UTILITIES ENGINEER of municipal electrical and water system—B.E.E. degree (Power) desires managerial or similarly responsible position with municipality or co-op. Immediate availability. Box 494.

ENGINEER—B.S.E.E. Power, Eta Kappa Nu, 35, family, 2 years instrumentation, 5 years general electrical utility distribution engineering, 3 years in charge system operation and maintenance medium-sized municipal utility. Available January 1, 1957. Prefer challenging position with emphasis on management in West or desirable foreign country. Box 495.

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A.I.E.E. TRANSACTIONS back volumes wanted to buy for cash and other periodicals—E. E. ASHLEY, 27 East 21st Street, New York 10, New York.

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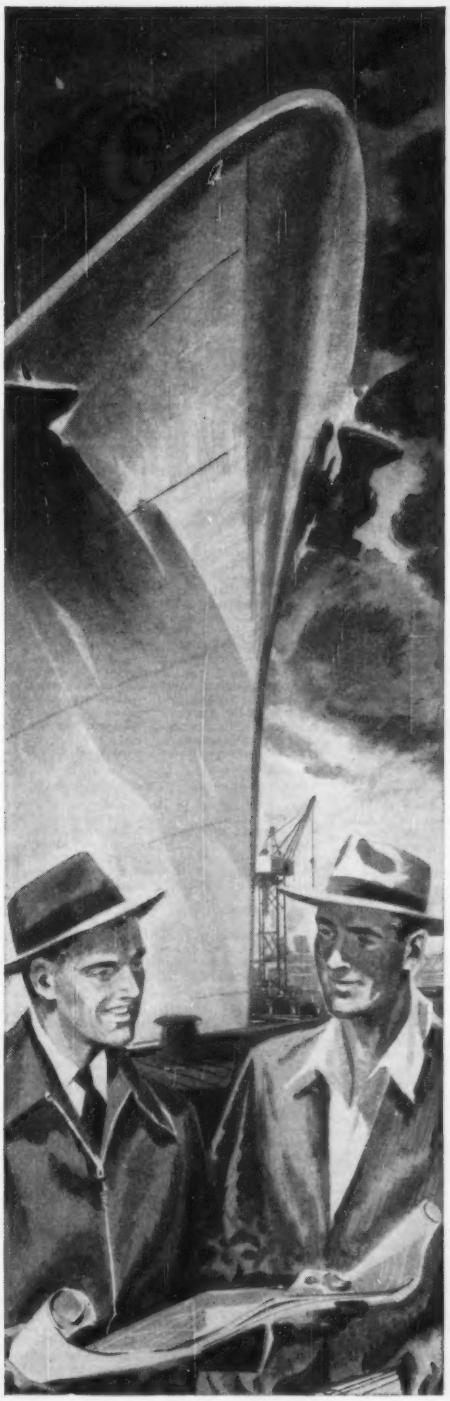

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**Two weekly bulletins of engineering positions open, one covering positions on the Pacific Coast and the other covering Midwestern and East Coast positions, are published and each is available to members at a subscription rate of $3.50 per quarter or $12.00 per annum, and to nonmembers at $4.50 per quarter or $14.00 per annum.**

## Men Available

STAFF OR MAINT. ENGR; BSEE; 29; 4½ yrs elec.-mech engrg and maint in the mining industry; 2 yrs util des and constr; 3 yrs military electronics. Prefers to locate in lower Michigan but will consider midwest or west. E-882-580-Chicago.

RESEARCH ENGR, Elec. Conductors; BSEE; 38; wishes association with program leading to new devpmts in materials used in trans and distr of elec pwr; 10 yrs public util trans-distr engr; 5 yrs military wire communications. Location immaterial. E-883-San Francisco.

PLANT ENGR, BS in EE; 42; experd in constr, maint, opern of light and heavy indus elec eqpt, substations, trans and distr (3 yrs. large underground copper mine and reduction plant). Location immaterial. E-884.

## Positions Available

SALES ENGINEERS, 2, graduate electrical, to sell a complete line of servo motors and component parts. Salary, $7500–$10,000 a year. Territories: West New York State, Pennsylvania and Ohio and Pacific Coast. W-3806.

ELECTRICAL ENGINEER, graduate, with from two to three years' experience, to handle engineering jobs for manufacturer of motors and generators. Salary, $7000–$8000 a year. Location, Connecticut. W-3829.

ENGINEERS. (a) Electrical Engineers for electrical control equipment; graduates, for from six to 12 months training period preparatory to assignment to development, application or control engineering duties. Base starting salary, depending on experience, $5100–$8400 a year. Give salary requirement when applying. (b) Field Sales Engineers, graduate electrical, for company in the control field. Job requires participation in application and service of custom built motor control for heavy industry. Will be given intensive training course. Give salary requirements when applying. Company will pay placement fees. Location, Ohio. W-3849.

PERSONNEL SUPERVISOR, mechanical or electrical graduate, with at least five years' supervisory staff liaison and recruiting experience in electro mechanical equipment field. Salary, $15,000 a year. Location, New York area. W-3868.

SALES SUPERVISOR, under 30, graduate electrical, with sales experience in the electrical field. Will be responsible for sale and distribution of mica and varnish cambric insulating materials in the northeastern section of the U. S. Will also supervise clerical and administrative staff in home office. Considerable time will be spent visiting customers and engaging in liaison work with sales staff. Starting salary open. Headquarters, Conn. W-3889.

PROFESSOR, electrical graduate, with teaching and industrial experience, to head up electrical engineering program for non-electricals, covering circuits and machines through electronics and instrumentation. Salary and rank commensurate with training and experience. Location, upstate New York. W-3915(a).

ELECTRICAL ENGINEER, graduate, about 30, with several years' experience in the operations of a utility company in production, transmission, and distribution and some administrative experience or potential. Excellent opportunities for advancement. Location, Latin America. F-3929.

ELECTRICAL INDUSTRY TECHNICAL ADVISER for Metals Trade Industry Center; graduate electrical engineer, thoroughly grounded in basic theory in order to solve problems connected with small motor manufacturing. Should have about ten years' manufacturing experience, principally in the small motor field; must have broad experience in planning production; selection of machinery and equipment; manufacturing methods; rough cost estimating and supervision of employees. Salary open; about 5% increase over best rate in past few years, plus 20% addition to base pay for period actually spent on assignment; U. S. currency. Transportation for family; free housing. Will work for American contractor on technical assistance program. Location, Far East. F-3933.

PROJECT ENGINEER, electrical or mechanical graduate, with at least eight years on electro-mechanical devices including servos and transistors. Salary, $8000–$10,000 a year. Location, New York, N. Y. W-3947(a).

CHIEF SYSTEMS ENGINEER to assist in organization and direction of a new engineering group for engineering systems from development through production phase; B.S.E. or M.S.E., preferably with concentration in electronics, servo mechanisms and/or physics. Must have experience in design and development of all types of airborne analog computers and servo mechanisms for control purposes; must be familiar with aerodynamic parameters and their use in control computers; should be familiar with general military specifications for avionic equipment, including environmental and performance requirements. Salary open. Company will pay placement fees and relocation expenses. Location, suburban New Jersey. W-3954.

DIRECTOR for new product development, graduate electrical, under 50, with at least ten years' responsible experience in the field of electronics and proven record of accomplishment in both design work and supervision; experience in development and manufacture of electronic components and specifically of capacitors is highly desirable. Should be capable of estimating manufacturing costs, predicting development progress and evaluating product marketability. Salary open. Location, Massachusetts. W-3956.

SALES ENGINEERS, young, electrical graduates or equivalent, with sales experience, to sell electrical testing instruments. Salary, $5000–$7000 a year. Locations: one for Chicago, Ill., and one for Philadelphia area. W-3965.

EDITOR, electrical engineering graduate, with at least five years' broad industrial experience covering electrical equipment in manufacturing and process industries. Salary, $7000–$8000 a year. Location, New York, N. Y. W-3970.

ELECTRICAL ENGINEERS. (a) Senior Electrical Engineer for development work, graduate, with a minimum of five years' experience in the design and development of small precision electromechanical devices for military applications; familiar with military specifications. Knowledge of servo systems very desirable. Must be capable of preparing sales estimates and quotations. Salary, $9000–$11,000 a year, depending upon experience and qualifications. (b) Electrical Engineer, graduate, for development work, with a minimum of two years' experience in the design and development of small precision electromechanical devices for military applications. Will assist senior engineer. Salary, $7000–$9000 a year, depending upon experience and qualifications. Company will pay placement fees. Location, Long Island, N. Y. W-3979.

EDITOR, graduate electrical engineer, to 40, with electric utility experience. Some editorial or writing experience desirable. Salary open. Location, New York, N. Y. W-3998.

INSTRUMENT APPLICATION ENGINEER, under 65, degree in electrical or mechanical engineering, with instrumentation experience in heavy chemical plants. Five years' experience in design of systems, maintenance and installation. Supervisory experience desirable. Will be responsible for selection of equipment for instrumentation systems for new plant. Supervise instrument draftsmen working on installation drawings. Salary open. Location, California. W-4018.

ELECTRICAL ENGINEER, 30–45, degree in electrical engineering, with a minimum of five years' in a heavy chemical plant. Must be familiar with controllers, motors, distribution systems, etc. Will be responsible for reviewing electrical drawings for new chemical plants and advising as to changes for efficient and economical installations. Will act as liaison engineer between architect engineer and employer. Salary open. Location, California. W-4019(a).

ELECTRICAL OR MECHANICAL ENGINEER, graduate, 38–44, with broad knowledge of air conditioning equipment and with five to ten years' experience with subcontractor on estimating, design and construction of complete systems. Competent to analyze drawings and specifications, analyze bids and participate in closings. Must have reputation for technical competence. Salary, $18,000–$20,000 a year. Location, East. W-4020.

STAFF ENGINEER, graduate electrical, 26–35, to handle electrical problems associated with plant engineering. Must have strong mechanical background in order to develop competency for complete machine design of special purpose machine tools and process equipment, with particular emphasis on the associated electrical and hydraulic controls necessary for automation. Salary open. Location, Pennsylvania. W-4031.

ELECTRICAL ENGINEER, 25–50, graduate electrical with a minimum of five years' experience in industrial electrical engineering work. Must have experience in range drive and control work; experienced in board work and willing to do some board work. Position is in Central Engineering Department. Salary, to $7200 a year. Location, Newark, N. J. area. W-4036(a).

CHIEF DEVELOPMENT ENGINEER, electronics, to take charge of the development of electronic instrument work on temperature pressure, liquid flow, recording instruments. Salary, $10,000–$15,000 a year. Location, New York State. W-4039.

ELECTRICAL ENGINEERS. (a) Electronics Research Engineer, graduate electrical, specializing in electronics, with four to seven years' industrial or research experience. Experience in radar, television or oscilloscope, design and development desirable. Will be responsible for circuit design of pulse networks, including non-sinusoidal applications such as saw-tooth, square wave, rectangular wave, etc. Salary, $7000–$9000 a year. (b) Electronics Research Engineer, graduate electrical, specializing in electronics, with four to seven years' industrial or research experience. Will be responsible for design of test equipment. Experience in wide-band oscillographs, spectrum analysers or square wave generators desirable. Salary, $7000–$9000 a year. Location, northern New Jersey. W-4044.

TEST EQUIPMENT ENGINEER, young, with heavy background in electronic circuits and controls and experience in test gear; amateur radio helpful. Will work on development of test equipment by application of electronic and mechanical circuits and principles; supervise and conduct experiments for development and improvement of test equipment, etc. Salary, $5772–$6240 a year. Location, Pennsylvania. W-4054.

ELECTRICAL ENGINEER with administrative background and knowledge of design, for overseas assignment. Salary, $7800–$10,200 a year, plus overseas differential of 25%. Location, Korea. F-4066.

ELECTRICAL ENGINEERS. (a) Designer, electrical, for electrical design on chemical and industrial plants. Salary, to $8700 a year. (b) Electrical Draftsmen for electrical layouts on chemical and industrial plants. Salary, to $7500 a year. Location, New York, N. Y. W-4067.

PROJECT ENGINEER, graduate electrical, with five years' experience in design and installation of secondary network power centers; industrial power and lighting. Will be responsible for design and layout of electrical systems; preparation of contract drawings and specifications; checking contractors' drawings; making installation inspections; making plant power and lighting surveys; preparation of reports and recommendations. Should have knowledge of code and utility requirements; knowledge of techniques of specifications and report writing. P. E. license desirable. Salary open. Location, Newark, N. J. W-4080.

ELECTRONIC APPLICATION AND INSTALLATION ENGINEER, 35–55, with at least five years' in utilization of carrier or telephone or telegraph equipment; know communications systems. Will do field work on application and installation of field equipment based on original survey. Salary, to $11,000 a year. Employer will pay placement fee. Location, Foreign and Domestic. C-5299.

ELECTRONIC SENIOR ENGINEER, electrical graduate, to 50; five years' design, development and system analysis of radar communications, etc.; know military electronics. Will design equipment, develop processes and conduct research. High degree of independent thinking required; for a manufacturer of electronics. Salary, $7000–$11,000 a year. Employer will pay fee. Location, upstate New York. C-5434.

JUNIOR ELECTRONIC ENGINEER, electrical graduate, to 50; with at least one years' development or design on electronic equipment and/or systems. Know military electronics. Will conduct environmental testing of equipment, checking for performance, making reports. Salary, to $7700 a year. Employer will pay fee. Location, upstate New York. C-5435.

COMPONENT ENGINEER, electrical graduate, to 50; with at least one year's experience in design, testing or application of resistors, capacitors, filters and similar components; know military electronics. Should have ability to carry out a project with a minimum of supervision; able to discuss project with others and make reports. Salary, to $10,000 a year. Employer will pay fee. Location, New York, N. Y. C-5436.

SENIOR ELECTRONICS DEVELOPMENT ENGINEER, 25–45, with at least three years' in transistor circuitry design or development; know servo amplifiers and servo mechanisms. Will direct development program for transistor circuitries for computors for a manufacturer of electronics. Salary, $10,000–$14,000 a year. Employer will pay placement fee. Location, Wisconsin. C-5564.

COMPUTOR DEVELOPMENT ENGINEER, 25–45, with at least three years' in aerodynamics for jet aircraft; know synchros, servos, kick-off and ray generators. Will develop airborne analog computors for a manufacturer of electronics. Salary, $10,000–$12,000 a year. Employer will pay placement fee. Location, Wisconsin. C-5565.

**NOTE: Closing date for material to be set in the classified advertising column, as well as cancellations for running ads, must be received not later than the first of the month preceding issue; i.e., July first for August issue.**

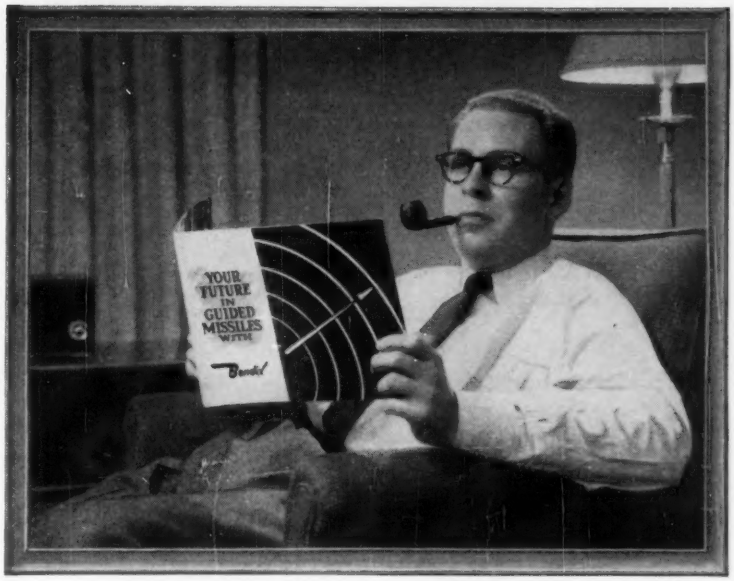
ELECTRICAL ENGINEER, BSEE, 30–50, with five years' experience in design of industrial lighting and electrical power installations; know chemical and process industry. Will act as project engineer handling all phases of electrical work for new plants and the expansion of present plant facilities. Also making up surveys and preparation of reports on existing plant electrical services. Limited travel. Company manufactures paint. Salary, to $8500 a year. Employer will pay placement fee. Location, Chicago, Ill. C-5622.

PRODUCT DESIGNER, Flashlights, to 40, with at least five years' in production tooling or production engineering; know metal forming, drawing, stamping, fabrication and assembly. Duties will be to design flashlights and related products for mechanized productions. Salary, to $8400 a year. Employer will pay placement fee. Location, Wisconsin. C-5629.

MONOCHROME T. V. RECEIVER ENGINEER, electrical graduate, 30–50, with at least three years' in all phases of T. V. design and simplifications; knowledge of semi-conductors and wide angle considerations helpful. Will provide technical guidance for electronic component circuitry to insure optimum performance and compatibility; for a manufacturer of electronics. Salary to $7800 a year. Employer will pay placement fee. Location, Chicago, Ill. C-5643.

ELECTRONICS SYSTEMS ENGINEER, graduate electrical, physics or math, with at least three years' experience on development of servomechanisms, electronics or instrumentation on airborne controls. Will do project work in development on above mentioned types of controls for a manufacturer of turbo jets. Salary, to $10,260 a year. Employer will pay placement fee. Location, Ohio. C-5645.

ELECTRICAL DESIGNER, graduate, 30–45, with at least five years' experience on heavy electrical equipment application; know motor control from 5–500 HP. Will design and develop control applications, improving present design, carry out experimental work and supervise small crew of draftsmen. Company manufactures heavy machinery. Salary, $7800–$10,800 a year. Employer will pay placement fee. Location, Wisconsin. C-5666.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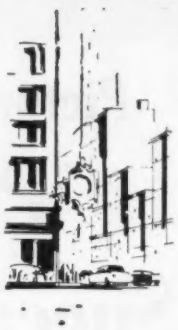

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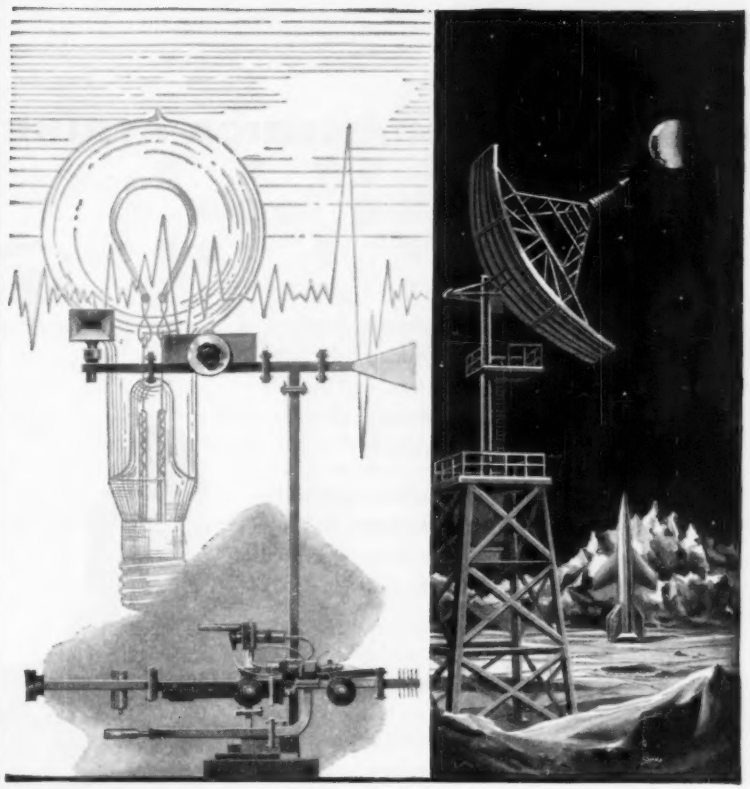

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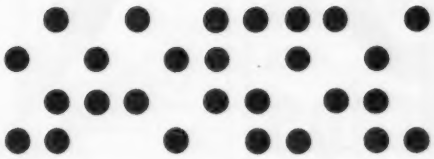

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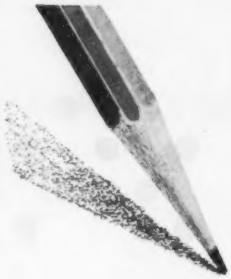

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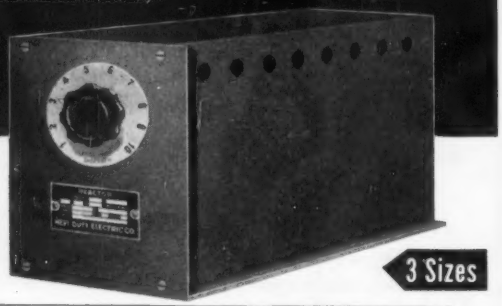


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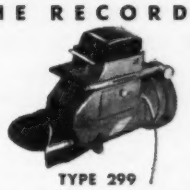

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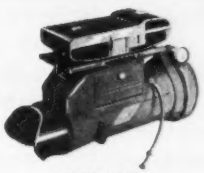

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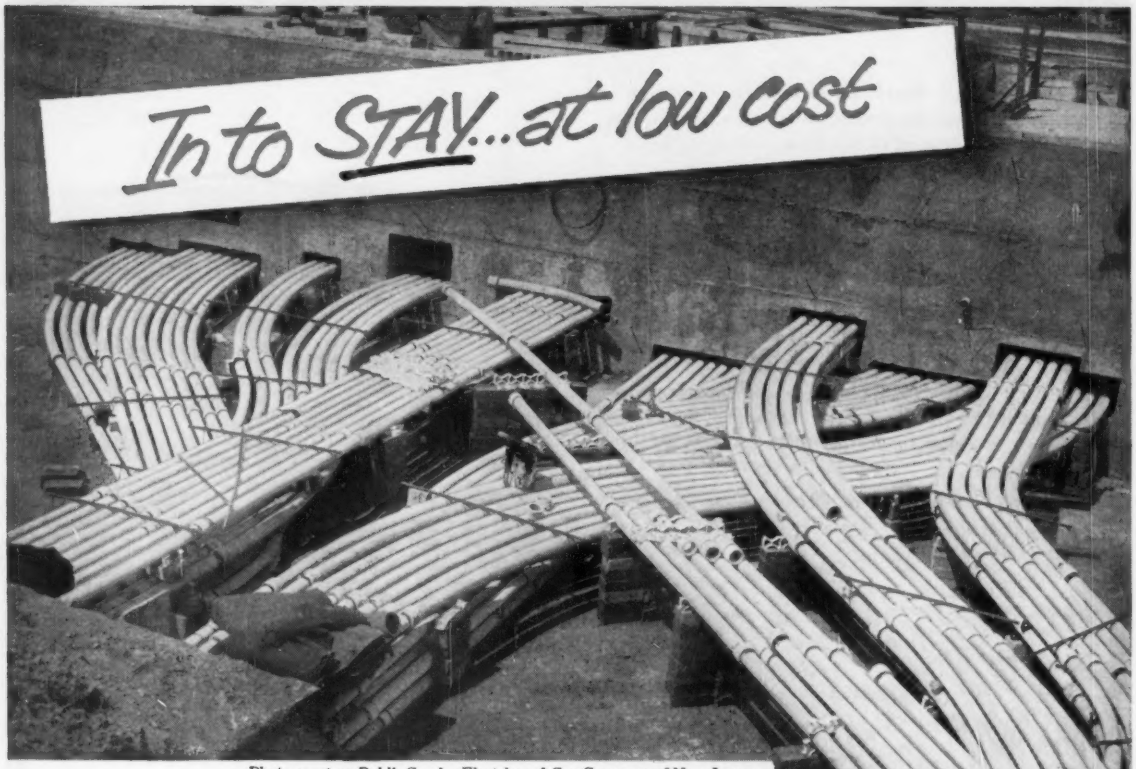


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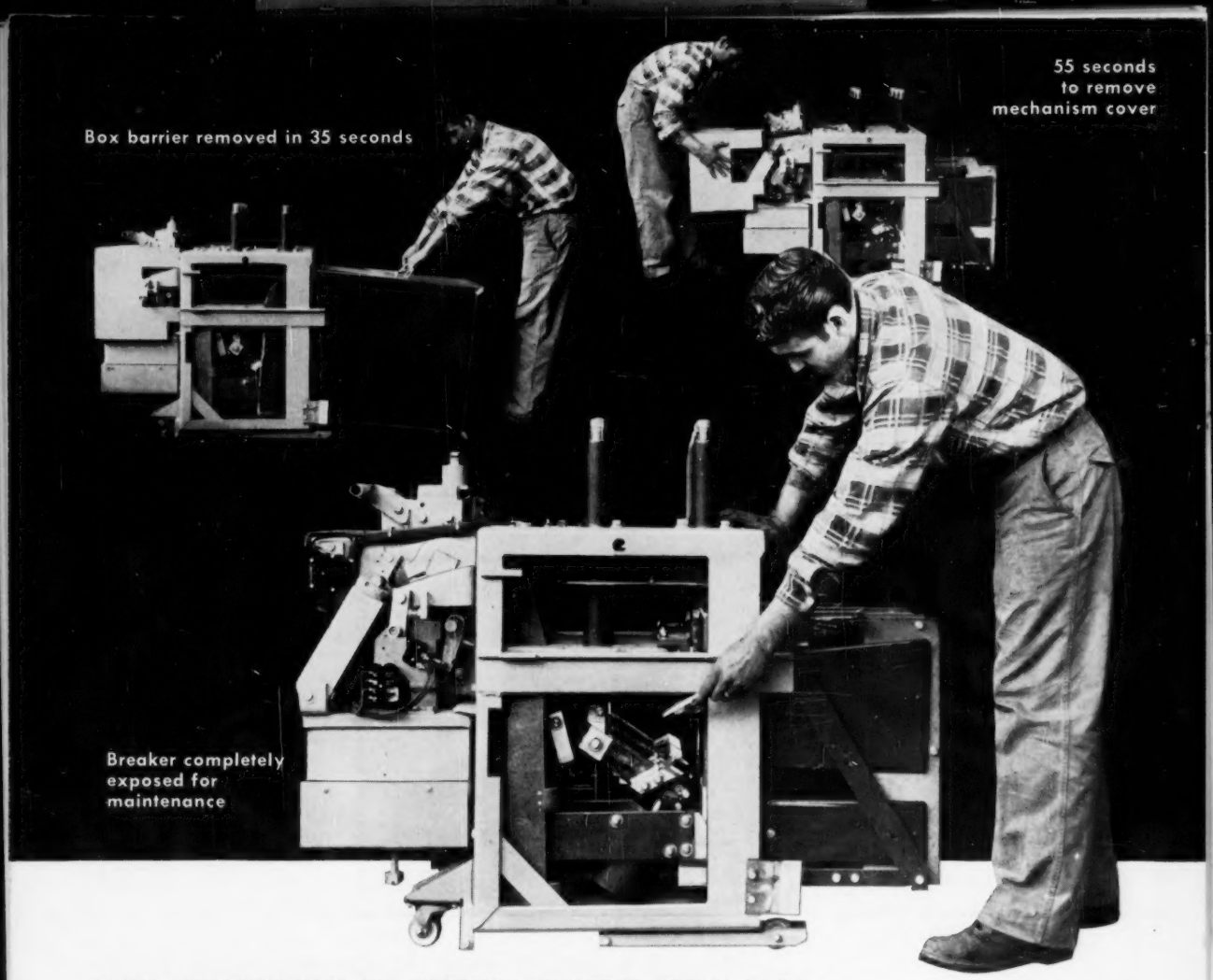


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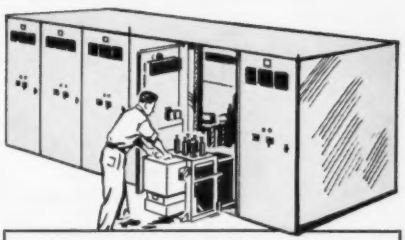

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- 5-CYCLE CLEARING TIME
- EASIER MAINTENANCE
- EXTRA STRONG FRAME